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JAMES RIVER BASIN WATER POLLUTION INVESTIGATION

Public Health Service
Kansas City, Missouri

April 1952

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JAMES RIVER DRAINAGE BASIN

A COOPERATIVE STATE - FEDERAL REPORT ON WATER POLLUTION

APRIL 1952

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Missouri River
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KAN.

NORTH DAKOTA
Department Of Health

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North Dakota. State Dept. of Health.

JAMES RIVER BASIN
WATER POLLUTION INVESTIGATION

April 1952

Prepared by:

STATE OF NORTH DAKOTA
STATE DEPARTMENT OF HEALTH

STATE OF SOUTH DAKOTA
STATE DEPARTMENT OF HEALTH

PUBLIC HEALTH SERVICE
DIVISION OF WATER POLLUTION CONTROL
MISSOURI DRAINAGE BASIN OFFICE

At the request of and in cooperation with
the BUREAU OF RECLAMATION

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Public Health Service Publication No. 187

JAMES RIVER BASIN

WATER POLLUTION INVESTIGATION

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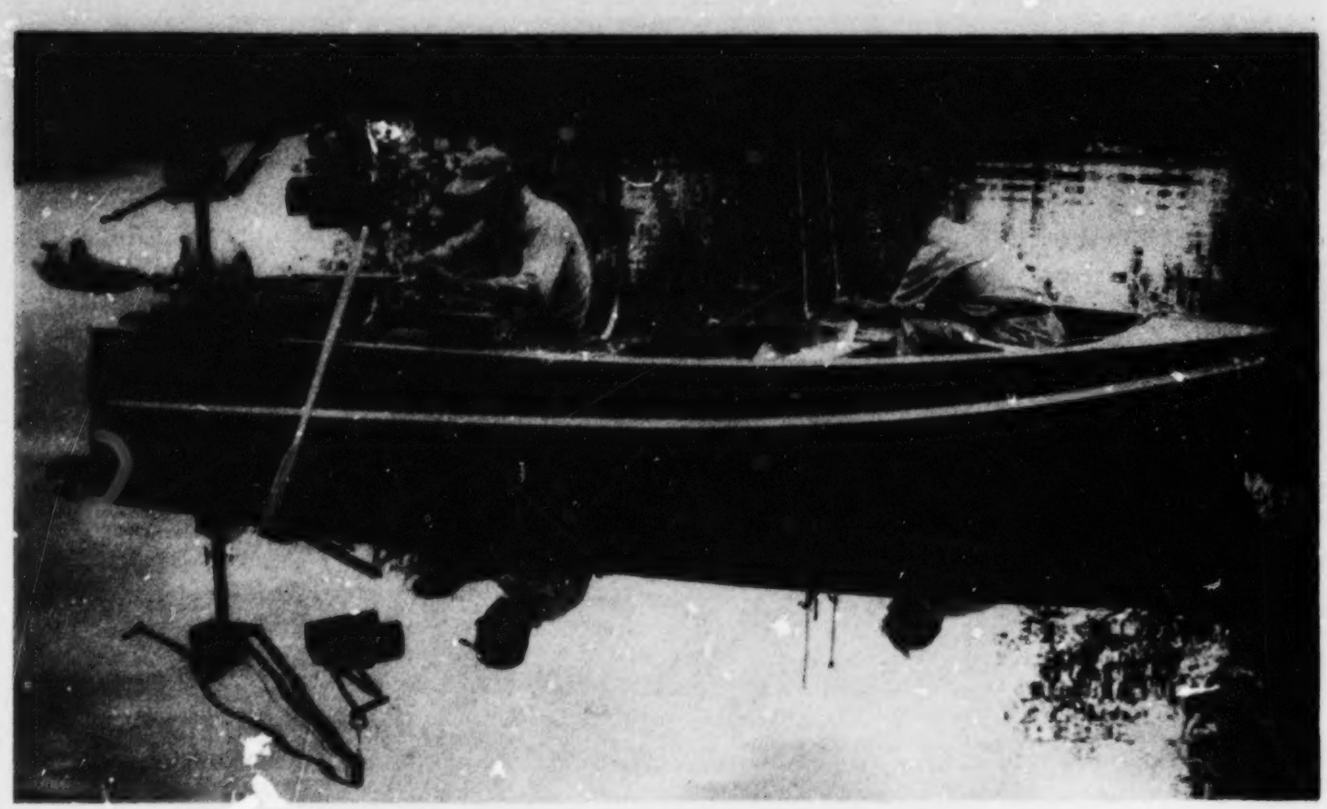
Above: James River northeast of Aberdeen, S.D., Sept. 13, 1951.

Below: Ice breakup on James River east of Redfield, S.D., April 5, 1951.



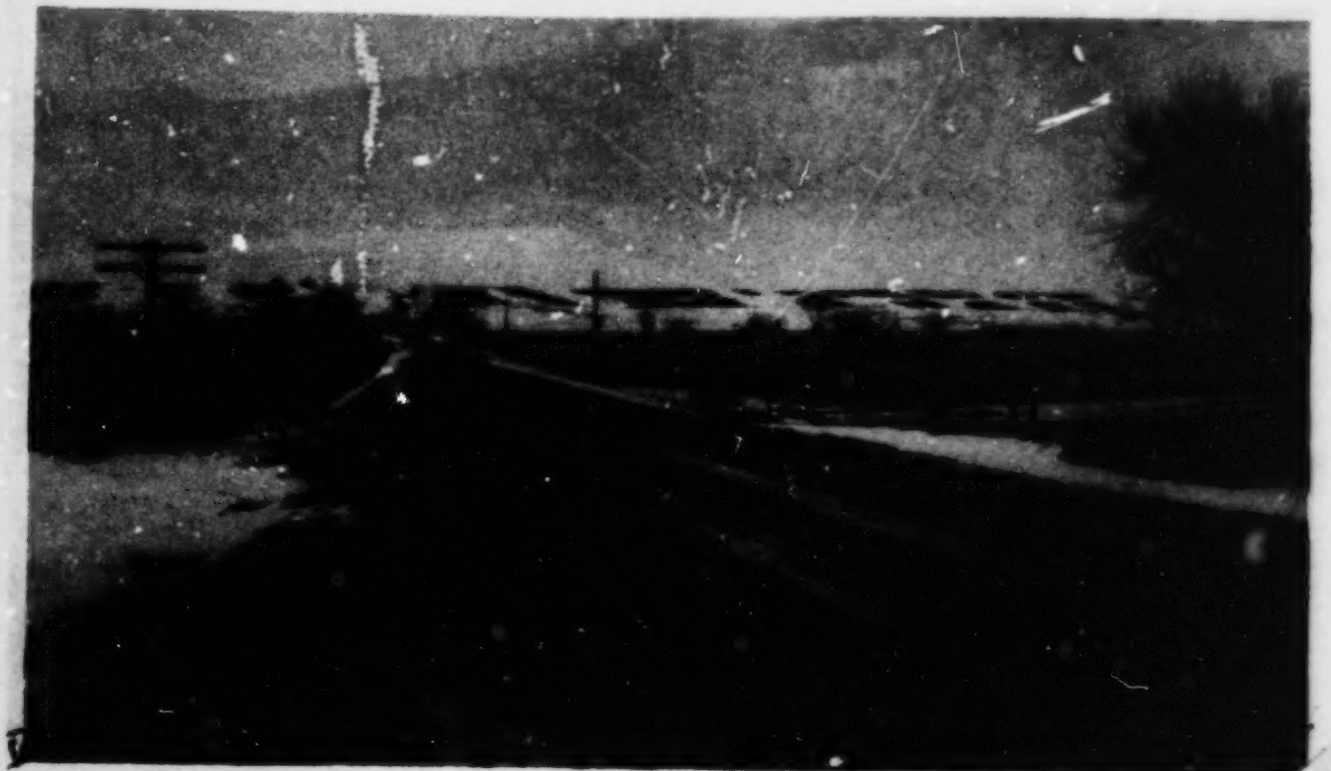
Above: Boat equipped for limnological survey operating on James River.

Below: Discharge over Huron, S.D., water works dam, April 2, 1951.

Reproduced from best available copy.

Above: Lampes Dam on James River below Huron, S.D., Sept. 11, 1951.

Below: James River spread over valley above Mitchell, S.D., April 4, 1951. Regular channel at base of hill in background.



INTRODUCTION

Development of the James River Basin proposes increased utilization of the land and water resources of the area. In the past severe droughts have occasioned population emigration due to crop failure. Contemplated improvement of existing resources includes importation of water from the Missouri River, leading to higher water uses and support of an expanded economy. Successful maturation of the development depends, among other things, upon protection and improvement of public health and includes water supply, sanitation and recreation. This necessitates appropriate evaluation of water requirements, which must be founded upon reliable information of water quality, and sources, types, and amounts of pollution contributed to streams.

Representatives of the Bureau of Reclamation, Department of the Interior, the State Water Pollution Control Agencies of South Dakota and North Dakota, and the Public Health Service, jointly agreed that the Public Health Service would assume primary responsibility for a cooperative report covering this investigation. A Memorandum of Understanding between the Bureau of Reclamation and the Public Health Service was prepared and became effective January 8, 1951 (appendix A).

The Memorandum of Understanding Respecting Joint Program for Public Health Investigations of the James River Basin states that "the scope of such report and studies thereunder shall include: (a) the extent, types, and major sources of pollution; (b) a review of existing laws and pending legislation regarding pollution of public waters in the States of North Dakota and South Dakota; (c) minimum stream flows necessary for public water supplies and other miscellaneous purposes, and for sanitation purposes as related to present and possible future pollution; (d) quality of water for municipal requirements and other miscellaneous purposes; (e) public health benefits of water pollution abatement resulting from the conservation, regulation, and use of water supplies under the Missouri River Basin program; (f) recommendations for pollution abatement and existing plans therefor; (g) effect of current and possible future pollution on water to be used for irrigation; and (h) other public health considerations of the water development program in the Basin."

The Missouri Drainage Basin Office, Division of Water Pollution Control, Public Health Service, in close cooperation with the respective State water pollution control agencies, initiated development of the water pollution investigations of the James River Basin immediately after the Memorandum of Understanding became effective. Activities were carried out jointly with the State water pollution control agencies and in close cooperation with various Federal agencies, who furnished laboratory assistance, information on water supply use, sources of pollution, stream flows at various points, and helped in other phases of the work.

AUTHORITY

This report has been compiled to fulfill the obligation incurred by the Public Health Service pursuant to a Memorandum of Understanding entered into January 8, 1951, by the Bureau of Reclamation and the Public Health Service.

ACKNOWLEDGMENT

The Water Pollution Investigation of the James River Basin was made possible through the excellent cooperation, assistance, and support given by interested State and Federal agencies, communities, and representatives of industry who were contacted during the survey. This opportunity is taken to gratefully acknowledge help provided by all.

The investigation was initiated following completion of the Memorandum of Understanding entered into by Region 6, Bureau of Reclamation, represented by Regional Director K. F. Vernon, who has done much to promote these activities, and the Missouri Drainage Basin Office, Public Health Service, represented by Glen J. Hopkins, Officer in Charge.

Special recognition is made of the support and cooperation of the Water Pollution Control Agency of South Dakota represented by Dr. G. J. Van Heuvelen, State Health Officer, and Charles E. Carl, Director, Division of Sanitary Engineering; the State Water Pollution Control Agency of North Dakota represented by Dr. R. O. Saxvik, State Health Officer, and Jerome H. Svore, Director, Environmental Health Service; the Missouri-Souris District of the Bureau of Reclamation at Bismarck, North Dakota, represented by District Manager Bruce Johnson, and Missouri-Oahe District of the Bureau of Reclamation at Huron, South Dakota, represented by District Manager Joseph W. Grimes.

Stream flow information was provided by the U. S. Geological Survey, Department of the Interior. Reports of the Fish and Wildlife Service, Department of the Interior; and the Corps of Engineers, Department of the Army, were used extensively. Data from the Census Bureau, Department of Commerce, and the Soil Conservation Service, Department of Agriculture, also contributed to the report.

Technical reviews of this report were made by the Division of Water Pollution Control, Public Health Service, Washington, D. C.; the Environmental Health Center, Public Health Service, Cincinnati, Ohio; interested State agencies; and the following Federal agencies: Bureau of Reclamation, Billings, Montana; Corps of Engineers, Omaha, Nebraska; Federal Power Commission, Chicago, Illinois; Department of Commerce, Denver, Colorado; Fish and Wildlife Service, Billings, Montana; National Park Service, Omaha, Nebraska; Department of Agriculture, Lincoln, Nebraska; and U. S. Geological Survey, Rolla, Missouri.

The water pollution control agencies of North Dakota and South Dakota, co-authors of this report, have given their approval of the contents as it applies to their respective States.

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SUMMARY

The James River drainage basin is located in the Central Lowland Province of the interior plains. From its headwaters near Fessenden, North Dakota, the river flows 710 miles to join the Missouri River east of Yankton, South Dakota. The James is intermittent in its headwater regions and becomes a constantly flowing stream in the vicinity of Huron, South Dakota.

Climate is subhumid. Precipitation ranges from 18 inches in the northern section of the Basin to about 25 in the southern part; about 75 percent occurs in the growing season. Agriculture, including livestock raising and related industries, forms the basis of economy.

Irrigation has been extremely limited and history of successful agriculture has been closely allied with availability of sufficient precipitation. Importation of Missouri River water will act to stabilize agricultural production, and to provide recreational facilities, fish and wildlife conservation, improved municipal water supplies, public health and sanitation benefits and hydroelectric power. Six dams and regulating reservoirs are under consideration.

Ground water supplies, varying in quality and quantity, are used to serve about 24,000 people of 17 communities in North Dakota, and 63 communities with almost 36,000 people in South Dakota. Three cities in South Dakota use surface sources to service a population of approximately 46,000. Considerable difficulty is experienced in obtaining ground water chemically suitable for human consumption. Ground water supplies are generally high in total solids, sulfates, iron, manganese, and hardness; and high fluoride and nitrate concentrations have been recorded at various locations. Water treatment has been instituted at about 25 percent of the communities. Redigging of wells to higher yielding aquifers has been necessary because of overpumping of ground waters. Adequate, readily available, surface sources of better quality resulting from the land and water resources development program would stimulate urban and rural improvement.

Industry uses ground and surface water for processing and cooling. Industrial establishments generally obtain water from municipalities. Most water used industrially is softened.

Forty-eight communities with about 177,000 population equivalents and 14 industries with separate outfalls with almost 14,000 population equivalents of organic pollution discharge wastes to the James River and its tributaries. Treatment reduces the waste discharged about 55 percent. Problems of pollution are largely local in nature. Public health hazards result from consumption of natural ice harvested in areas where untreated or inadequately treated wastes have been discharged to watercourses. Polluted waters are not considered satisfactory for livestock watering. Use of polluted waters in the irrigation of low-growing crops such as lettuce, berries, tomatoes, and other truck farm products is considered unsafe.

A minimum of efficient primary treatment is required in the Basin by State water pollution control agencies and, where water uses warrant, a higher degree of wastes treatment is specified. Chlorination of treatment plant effluents may be required. Adequate treatment of municipal and industrial wastes reaching the James River and its tributaries would obviate local pollution problems and prevent public health hazards and nuisances. The cost of recommended treatment facilities based on existing conditions is conservatively estimated at $3,050,000.

Existing water pollution control laws and programs have been reviewed and recommendations include adequate State legislation and maintenance of a comprehensive pollution control program.

The land and water resources development program of the Basin is in an advanced stage of planning. Reservoir routing and stream regulation may effect a number of changes in the regimen of the river and its tributaries, and further study of the effects on public health and stream sanitation is indicated. Minimum desirable flows at pertinent locations are presented in tables 1, 26 and 27. Table 26 includes cost benefits for communities where flows that may possibly be provided by the development program permit a change in degree of required waste treatment. Annual benefits totaling approximately $150,000 resulting from stream regulation are possible under present conditions for the communities of New Rockford, La Moure, Oakes, Jamestown, Huron, Mitchell, Redfield and Aberdeen. Additional benefits may accrue in the future.

CONCLUSIONS

1. Water imported from the Missouri River and its development by the Bureau of Reclamation for maximum beneficial use will influence stream flow and those aspects of public health and sanitation affected by adequacy of stream discharges of the James River Basin. Effects remain contingent upon completion and execution of plans now in preparation and will require future investigations by health agencies.

2. Sources of water supply will be affected by the program. Many municipalities and industries may benefit by provision of adequate supplies of improved quality.

3. Surface water sources are used for potable supply by three communities to furnish 4 - 7 M.G.D. to a total population of approximately 46,000; 77 municipalities and 3 institutions use ground water sources to serve about 59,000 people.

4. Forty-eight communities and 14 industrial plants produce domestic and industrial organic wastes totaling about 191,000 population equivalents; seasonal wastes discharged by a large packing company in late fall and winter amount to over 38,000 additional organic population equivalents. Sewage treatment facilities reduce organic pollution, excluding seasonal wastes, about 55 percent.

5. Generally, pollution is local in nature and may be alleviated by efficient use of waste treatment facilities.

6. New municipal sewage treatment plants or improvement of existing plants are required at 30 communities; 15 need new plants; 2 need replacement of existing plants and 13 should have present facilities enlarged (table 2). Cost of constructing treatment facilities recommended in this report, based on existing conditions, is conservatively estimated at $3,050,000.

7. The State water pollution control agencies are progressing in their programs to abate pollution by educating sewage treatment operators and the public regarding effects of pollution, and by promoting new treatment facilities, enlargements, or additions to existing works. Additional funds and personnel are needed for proper execution of the program.

8. Cooperation between representatives of municipalities, and industries is good, and is reflected in practical agreements for use of municipal waste treatment facilities for reducing effects of contaminating industrial effluents.

9. Useful desirable minimum flows are based upon a minimum of primary treatment or upon existing higher degrees of treatment; secondary treatment desirable minimum flows are based upon a minimum of secondary treatment (table 26 - Flow needs and cost evaluation). Cost benefits will accrue to the development program provided desirable dilution flows are furnished which permit a lower degree of treatment. Table 1 lists the flow needs by months for critical locations for dilution of existing waste treatment plant effluents and estimated future (year 2000) primary and secondary treatment plant effluents.

10. Provision of satisfactory water supplies through the proposed development of water resources will result in substantial benefits.

11. Public health and sanitation aspects of water resource development, as illustrated in this report, merit appropriate consideration in the planning of the James River Basin Program.

RECOMMENDATIONS

It is recommended that:

1. A comprehensive program of water pollution control for the James River Basin be adopted by North Dakota and South Dakota.

2. The States provide financial support for their water pollution agencies to permit maintenance of an adequate staff of sanitary engineers and water biologists so that a comprehensive program of pollution prevention and abatement may be properly executed.

3. Sewage treatment be provided as recommended in table 2.

Table 1. James River Basin - Flow needs in c.f.s. for critical locations

	Jamestown, N.D.			Aberdeen, S.D.[a]			Huron, S.D.			Mitchell, S.D.		
	1	2	3	1	2	3	1	2	3	1	2	3
December-March, incl.	60[c]	210[c]	70[c]	70[c]	295[c]	90[c]	200[bc]	830[bc]	230[bc]	140[c]	700[c]	185[c]
April	20	90	25	20	90	25	30	180	50	30	180	50
May	25	100	30	25	100	30	45	220	60	45	220	60
June-September, incl.	35	120	40	35	120	45	65	300	85	65	290	80
October	25	100	30	25	100	30	100[b]	430[b]	115[b]	80	350	100
November	20	90	25	20	90	25	100[b]	430[b]	115[b]	80	350	100

[a] James River at Moccasin Creek.

[b] Seasonal industrial wastes add to pollution load.

[c] Ice cover.

[1] Flows (c.f.s.) based upon present population equivalents and removal by existing secondary treatment facilities (75 percent removal).

[2] Flows (c.f.s.) based upon an increase in population equivalents of 100 percent for period 1950-2000 and improved primary facilities (45 percent removal).

[3] Flows (c.f.s.) based upon an increase in population equivalents of 100 percent for period 1950-2000 and improved secondary facilities (85 percent removal).

Table 2. James River Basin - Sewage treatment requirements as determined by State water pollution control agencies having jurisdiction

	Treatment facilities		
Municipality	Existing	Required	Project
North Dakota			
New Rockford	Minor[a]	Secondary	New plant
Jamestown	Secondary	Higher degree of secondary or tertiary	New plant
Orleans Canning Co.	Lagoons	Higher degree of secondary	New plant
Stock Sales Co.	None	Primary	New plant
Railroad Maintenance Shops	None	Primary	New plant
La Moure	None	Secondary	New plant
Oakes	None	Secondary	New plant
Edgeley	Primary	Secondary	Addition
Ellendale	Minor[a]	Secondary	Addition
South Dakota			
Frederick	None	Secondary	New plant
Leola	Primary	Secondary	Replacement
Britton	Primary	Secondary	Addition
Andover	None	Primary	New plant
Groton	None	Secondary	New plant
Faulkton	None	Secondary	New plant
Redfield	Secondary	Secondary[b]	Addition
Doland	None	Secondary	New plant
Highmore	None	Secondary	New plant
Huron	Secondary	Higher degree of secondary	Enlargement
Lampes Packing Co.	None	Secondary	New plant
Wessington	Secondary	Secondary	Replacement
Wolsey	None	Secondary	New plant
Iroquois	Primary	Primary	Enlargement
Woonsocket	None	Secondary	New plant
Artesian	None	Secondary	New plant
Wessington Springs	Secondary	Secondary	Enlargement
Mitchell	Secondary	Higher degree of secondary	Addition
Mylan Meat Co.	None	Secondary	New plant
Mitchell Packing Co.	None	Secondary	New plant
Plankinton	Primary	Secondary	Addition
Mt. Vernon	None	Primary	New plant
Alexandria	Primary	Secondary	Addition
Parkston	Primary	Secondary	Addition
Bridgewater	None	Secondary	New plant
Menno	Secondary	Secondary	Enlargement
Aberdeen	Secondary	Higher degree of secondary	Enlargement

Table 2. James River Basin - Sewage treatment requirements as determined by State water pollution control agencies having jurisdiction (cont'd.)

	Treatment facilities		
Municipality	Existing	Required	Project
South Dakota (cont'd.)			
Aberdeen			
Langan Packing Co.	None	Secondary	New plant
Torigian Produce Co.	None	Secondary	New plant
N. W. Packing Co.	None	Secondary	New plant
Ethan			
Ethan Dairy Products	None	c	New plant
Dimock			
Dimock Dairy Products	None	c	New plant

[a] Septic tank.

[b] Includes units which will enable treatment of industrial wastes.

[c] A high degree of waste prevention or control.

4. Stream regulation resulting from the program of water resource development in the James Basin provide if possible the useful desirable minimum flows as presented in table 1.

5. Chlorination be provided where waste treatment plant effluents enter waters used for irrigation.

6. Chlorination be provided municipal water supplies showing evidence of contamination.

7. Study of water pollution be continued to keep pace with changes effected by the water and land resources development program, including municipal and industrial expansion.

HISTORICAL BACKGROUND

Prior to the coming of the white man, Sioux, Mandan, Hidatsa and Ree Indians inhabited the James River Basin. Their livelihood depended upon hunting and trapping and they constantly fought the invasion of their domain by white settlers.

The area was claimed for the King of France and Navarre by Sieur de la Salle in 1682. The first recorded visit of the French was by the Verendrye brothers who, in 1738, made formal claim for their government. Thereafter trappers, explorers, scientists, and soldiers traveled throughout the region. The James River, which has been described as the longest unnavigable river in the world, allegedly received its name from a French-Indian hunter-trapper who, having lost his way, was overcome with joy upon discovering the little river and gave it his name, "Riviere de Jacques."

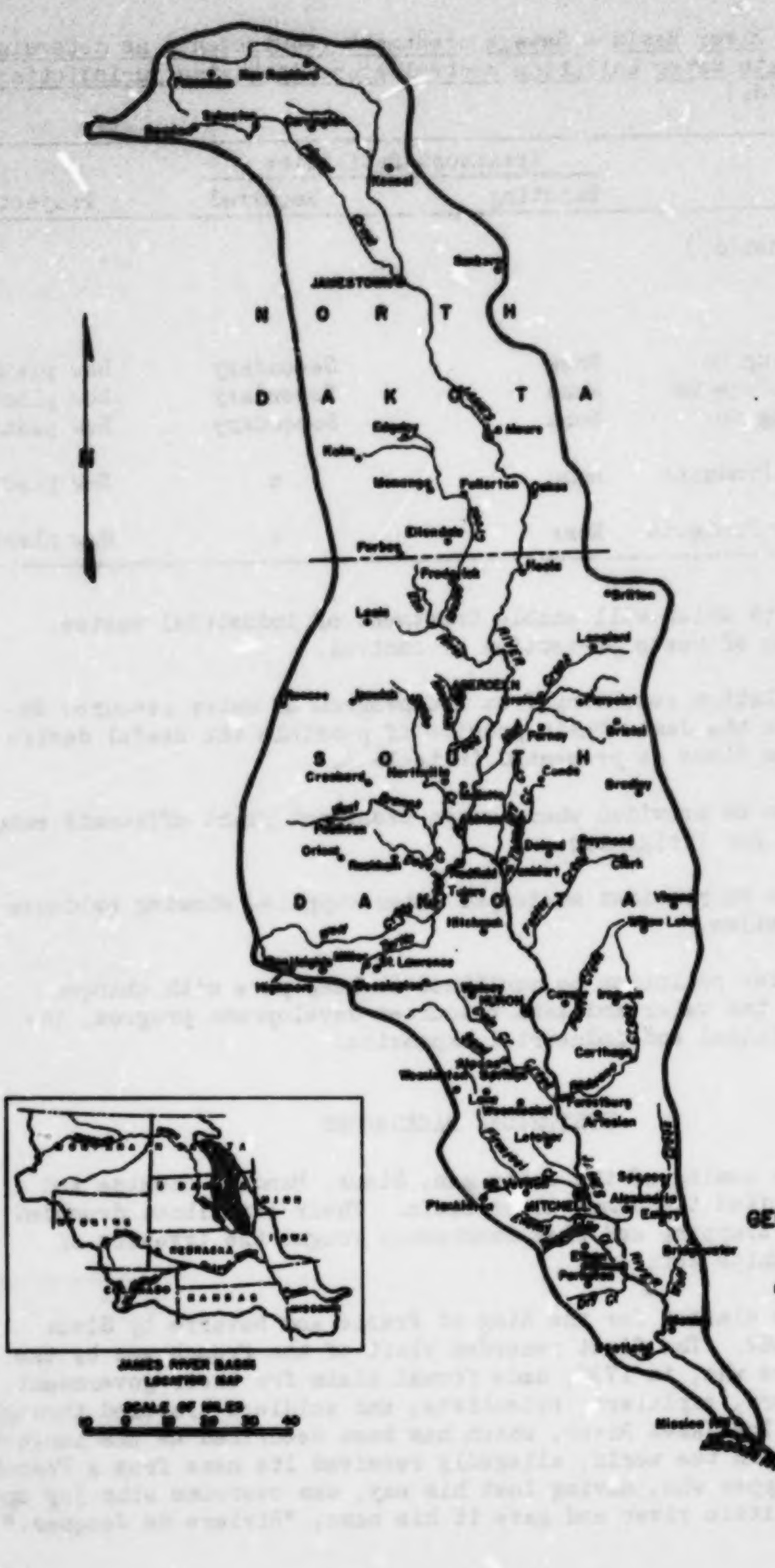
JAMESTOWN
Kensal
N O R T H
D A K O T A
Edgeley
Kulm
La Moure
Fullerton
Oakes
Ellendale
Forbes
Frederick
Hecla
Britton
Leola
Langford
ABERDEEN
RIVER
S O U T H
D A K O T A
Cresbard
Northville
Bristol
Conde
Bradley
Faulkton
Orient
Redfield
Doland
Raymond
Clark
Tulare
Hitchcock
Willow Lake
Highmore
St. Lawrence
HURON
Carthage
Woonsocket
Forestburg
Artesian
Letcher
Plankinton
MITCHELL
Alexandria
Emery
Spencer
Bridgewater
Parkston
Dry Cr.
Scotland
Mission Hill
Missouri River
JAMES RIVER BASIN
LOCATION MAP
SCALE OF MILES
10 0 10 20 30 40
N
NORTH DAKOTA
SOUTH DAKOTA
MINN
IOWA
NEBRASKA
WYOMING
COLORADO
KANSAS
MISSOURI

FIGURE 1

JAMES RIVER BASIN

GENERAL REFERENCE MAP

FEDERAL SECURITY AGENCY

Public Health Service

DIVISION OF WATER POLLUTION CONTROL

In 1803 the United States acquired title to the area. Following completion of the Lewis and Clark Expedition in 1806, American fur traders took over the region and remained in control until the trade declined in the middle of the 19th century. By that time the Basin had become studded with trading posts.

The new Dakota Territory, including the James Basin, was authorized by Congress in 1861. Growth was retarded by Indian disturbances, severe droughts, and grasshopper plagues. By 1868 the trial period was over. Temporarily the droughts ended, grasshopper pests abated, Indian wars ceased, and railway connections improved sufficiently to afford a wider market for crops. Settlements then extended half way up the James River. A decade of steady growth was interrupted by the grasshopper invasions of 1874, 1876, and 1877, after which the region resumed development. Progress was abetted by extension of railroads in the years from 1880-1889, favorable climatic conditions, and increased immigration due to the Great Dakota boom. More intensive farming soon developed. After 1886 an adjustment in farming methods was required since declining rainfalls in the period 1886-1897 caused temporary setbacks. The population decreased during the period of adverse financial conditions which reached a climax in 1893. Agriculture remains the main industry in the Basin, manufacturing being largely the processing of farm products.

PHYSICAL DESCRIPTION

Geography

The 22,100 square mile area of the James River Basin (figure 1) is divided between North Dakota (6,200 sq. mi.) and South Dakota (15,900 sq. mi.). The Basin is 350 miles long with a maximum width of about 100 miles. The river rises west of Fessenden, North Dakota, flows east for a short distance, and then follows a general southerly course through South Dakota to its confluence with the Missouri east of Yankton. Principal tributaries to the river are listed in table 3.

Table 3. James River Basin - Principal tritutaries and their drainage areas

Stream	Miles above mouth		Drainage area (square miles)
	James River	Tributary	
Pipestem Creek	578		618
Elm River	429		1,325
Willow Creek		39	
Maple River		45	
Snake Creek	300		1,651
West Branch		10	
Dove Creek		2	
Turtle Creek	290		1,163
Wolf Creek		25	
Sand Creek	177		
Firesteel Creek	139		417

Topography

The Basin, essentially a flat plain bounded by the Missouri River escarpment on the west and the Altamount, Antelope, and Gary moraines on the east, contains extinct glacial lakes whose beds are distinguishable by extremely flat topography. Lake Dakota formerly extended north from the region of Huron, South Dakota, to a point a few miles above the North Dakota-South Dakota boundary. Redfield is situated near the western edge and Aberdeen on the bed of this extinct lake. The Basin slopes from elevation 1,630 feet m.s.l. in the headwaters to 1,300 feet m.s.l. at the North Dakota-South Dakota line and 1,170 feet m.s.l. at the mouth of the James River. The river, requiring 710 channel miles to traverse the 350 mile length of the Basin, is a meandering stream lying in a shallow flood plain that varies from a few hundred feet to three miles wide.

Climate

Mean annual precipitations of 25 inches in the south and 18 inches in the north give the Basin a subhumid climate. Seventy-five percent of the precipitation occurs as rain during the growing season which ranges from 112 days in the north to 162 days in the south. High summer temperatures reach 110° to 120° F., while minimum temperatures of about -40° F. have been recorded. Average temperatures vary from 65° to 80° F. in July and from 1° to 19° F. in January, from north to south. Snowfall is generally light.

Hydrology

The drainage system is poorly developed and drainage lines are ill defined. Lakes, ponds, and marshes, common throughout the Basin, receive a large portion of the runoff and contribute to stream discharge only when they overflow--a rare occurrence in much of the area. Precipitation reaches the river largely by percolation through the earth, and much moisture is lost through evaporation and transpiration. A large portion of summer rains enters the ground, which also absorbs some winter snow and early spring rains.

Runoff amounts to a very small percentage of the annual precipitation. Highest stages of the James occur in March and April when stream flow is materially affected by melting snow. Peak discharges are frequently sustained by heavy rainfall through May and June. Annual low stages occur in late summer, autumn, and winter. The stream is normally intermittent down to Huron, South Dakota.

Channel capacity, usually 1,000 to 2,000 second-feet, reduces in some places to 500 c.f.s., causing isolated spring floods. Over-all slope, measured at low water level, amounts to approximately 0.68 feet per mile; of the 485 feet total drop in elevation, 330 feet or 68 percent occurs along the upper 185 miles. Nearly uniform slope characterizes the headwaters section. Fall along the lower three-fourths of the stream is only about 0.28 feet per mile. Backwater from numerous low head dams forms much of the river. A majority of tributary streams have steeper gradients than the James. Valley flooding is frequently occasioned by tributary discharges in excess of the carrying capacity of the James. Under these conditions the normal direction of stream flow in the James above the tributary may be reversed.

ECONOMIC DEVELOPMENT

The Basin has a population of approximately 220,000. Jamestown, with 10,697 (1950 census) people, is the largest community in the North Dakota section; six municipalities in North Dakota have populations in excess of 1,000. In South Dakota there are 14 communities with more than 1,000 inhabitants as shown by the 1950 census; Aberdeen has 21,051, Huron 12,788, and Mitchell 12,123. Three of 16 municipalities in North Dakota and 12 of 63 communities in South Dakota have 500 to 1,000 people (table 4).

The economy has developed upon an agricultural basis. Fifty-six percent of employed workers were occupied in agricultural activities (U. S. census 1940). In North Dakota 67 percent, and in South Dakota 52 percent of the employed were engaged in farming. Industry is primarily related to the processing of farm products. In 1940, sale of livestock amounted to 54 percent of total farm income. Raising of wheat and small grains predominates in the northern part of the Basin. Corn is the principal crop in the southern section. The Rural Level of Living Index in 1940 was about 114 as compared to a national level of 101.

Transportation facilities have been of great importance in development of the area. Through highways cross the Basin east and west and north and south. A system of market roads complements main highways and affords access to all parts. Seven railroads serve the region.

Population growth appears dependent upon future development of agriculture and expansion of related industries. Irrigation has not been extensively practiced. Introduction of planned irrigation will result in new agricultural products and an intensification of some of the existing agricultural operations.

The Bureau of Reclamation has tentatively estimated that existing slaughtering and meat packing plants could handle additional animals by stepping up production on a single shift. During the peak marketing season use of two shifts would almost double existing output. Present dairy plant capacity could absorb about nine million pounds of butterfat resulting from irrigation developments; poultry production increments could be handled by facilities now utilized. Annual production of potatoes could be increased by approximately 5.5 million bushels.

Population statistics from 1930 to the present show that the trend away from farms has continued in the Basin. Future population growth will depend upon provision of dependable water supply for municipal and industrial use, irrigation, and power. Preliminary studies by the Bureau of Reclamation indicate that with irrigation municipal population may increase 49 percent and farm population about 36 percent over a period of 25 years. Population forecasts are included in tables 5 and 6 and figure 2.

Table 4. [illegible] River Basin - Population of municipalities

Municipality	[illegible]	[illegible]	[illegible]	[illegible]
South Dakota (Cont'd)				
Letcher	[illegible]	[illegible]	[illegible]	[illegible]
Miller	[illegible]	[illegible]	[illegible]	[illegible]
Mitchell	[illegible]	[illegible]	[illegible]	[illegible]
Mt. Vernon	[illegible]	[illegible]	[illegible]	[illegible]
Wessington	[illegible]	[illegible]	[illegible]	[illegible]
Wessington Springs	[illegible]	[illegible]	[illegible]	[illegible]
Willow Lake	[illegible]	[illegible]	[illegible]	[illegible]
Wolsey	[illegible]	[illegible]	[illegible]	[illegible]
Woonsocket	[illegible]	[illegible]	[illegible]	[illegible]

Table 5. James River Basin - Forecast of population under development*

Year	Municipal	Other	Total
1950	104,446	115,943	220,389
1975	155,654	157,336	312,990
2000	223,075	175,904	398,979

*From Bureau of Reclamation preliminary estimate.

According to tentative estimates of the Bureau of Reclamation, development of 915,000 irrigable acres in Jamestown, New Rockford, Oakes, and Oahe units would service about 6,770 family size farms. Approximately 5,140 new farms would effect increases in future population, and increase annual farm sales by $45,000,000 when based upon 1939-1944 farm prices. Sales of livestock and associated products would make up 65 percent of this increase, and the remaining 35 percent would be derived from sale of corn, potato, sugar beet, and other intensive farm crops, hay, and small grains.

Table 6. James River Basin[1] - Forecast of municipal populations under conditions of planned resource development, 1950-2000

State	County	Municipality	1950	1975	2000
North Dakota	Dickey	Ellendale	1,747	2,211	2,709
		Ludden	90	265	508
		Oakes	1,759	2,537	3,107
	Eddy	New Rockford	2,187	3,261	3,995
	Foster	Carrington	2,083	3,032	3,714
	La Moure	Edgeley	900	1,086	1,330
		Kulm	800	965	1,182
		La Moure	1,002	1,391	1,704
	Stutsman	Jamestown	10,601	15,327	19,325
		Medina	650	785	961
		Streeter	700	844	1,034
	Wells	Bowdon	550	986	1,209
		Cathay	200	397	671
		Fessenden	1,000	1,637	2,006
		Sykeston	325	548	855
South Dakota	Aurora	Plankinton	725	875	1,071
	Beadle	Hitchcock	260	833	1,632
		Huron	12,713	19,006	29,019
		Virgil	120	404	801
		Wessington	507	820	1,249
		Wolsey	450	958	1,663
	Bon Homme*	Scotland	1,188	1,433	1,756
	Brown	Aberdeen	20,976	29,135	42,732
		Columbia	280	494	789
		Groton	1,072	1,293	1,584
		Hecla	600	1,035	1,268

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Table 6. James River Basin[1] - Forecast of municipal populations under conditions of planned resource development, 1950-2000 (cont'd.)

State	County	Municipality	1950	1975	2000
South Dakota (cont'd.)					
	Brown	Houghton	150	337	597
		Mansfield	205	506	927
		Stratford	262	316	387
		Warner	151	340	610
	Davison	Mitchell	12,062	17,607	24,569
	Edmunds	Ipswich	1,046	1,418	1,982
	Faulk	Cresbard	300	621	1,067
		Faulkton	900	2,128	3,827
		Orient	250	381	564
		Rockham	125	410	809
	Hand	Miller	1,902	3,851	6,555
		St. Lawrence	175	367	634
	Hanson	Alexandria	770	929	1,138
	Hutchinson	Freeman	1,000	1,206	1,477
		Menno	970	1,170	1,433
		Parkston	1,358	1,638	2,007
	Jerauld	Alpena	460	863	1,380
		Wessington Springs	1,450	2,057	2,943
	McCook*	Spencer	620	748	916
	McPherson*	Leola	872	1,052	1,289
	Marshall	Britton	1,404	1,905	2,456
		Langford	452	701	1,043
	Sanborn	Artesian	550	663	813
		Forestburg	170	309	501
		Woonsocket	1,041	1,619	2,411
	Spink	Ashton	218	419	697
		Athol	125	410	809
		Doland	507	612	749
		Frankfort	350	474	642
		Mellette	320	594	973
		Northville	250	510	869
		Redfield	2,642	8,142	15,823
		Tulare	200	500	920
	Yankton	Yankton	7,704	9,293	11,384
		Total	104,446	155,654	223,075

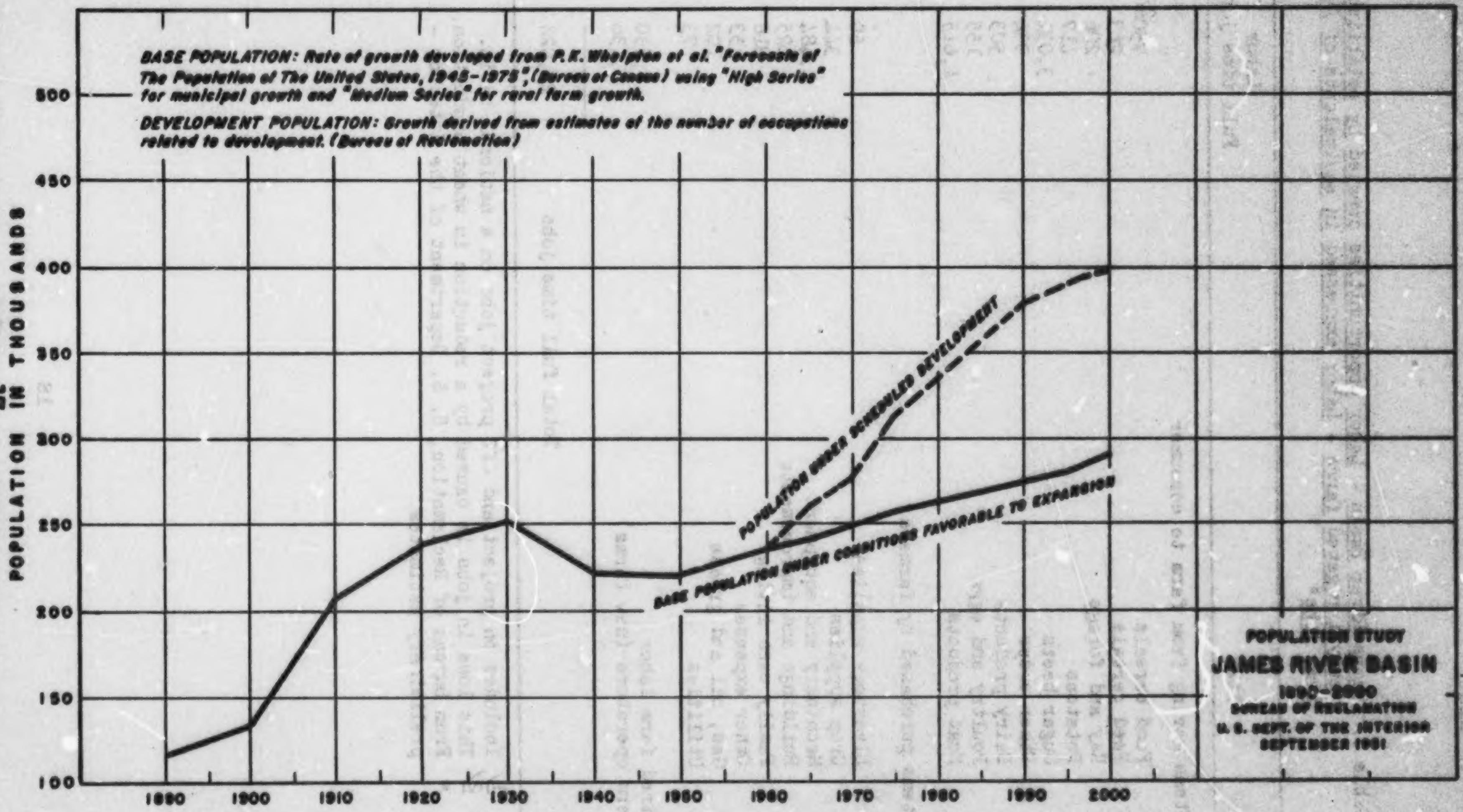
---

*Not included in County totals.

[1] From Bureau of Reclamation, Department of the Interior - preliminary estimates.

Table 7 lists labor opportunities which may be created by establishing newly irrigated farms and also gives distribution of labor by function. Omitted are professional categories such as doctors, nurses, engineers, teachers, and lawyers.

FIGURE 2



BASE POPULATION: Rate of growth developed from P.K. Whelpton et al. "Forecasts of The Population of The United States, 1945–1975", (Bureau of Census) using "High Series" for municipal growth and "Medium Series" for rural farm growth.

DEVELOPMENT POPULATION: Growth derived from estimates of the number of occupations related to development. (Bureau of Reclamation)

POPULATION STUDY
JAMES RIVER BASIN
1890–2000
BUREAU OF RECLAMATION
U. S. DEPT. OF THE INTERIOR
SEPTEMBER 1951

Table 7. James River Basin - Labor opportunities created by establishing newly irrigated farms - Labor expressed in equivalents of full-time jobs*

Item	Labor Full time jobs[1]
Items moving from farm to consumer	
Food cereals	750[2]
Feed cereals	263
Hay and forage	206
Potatoes	417
Sugar beets	3,031
Other crops	934
Dairy products	503
Poultry and eggs	155
Meat products	4,615
Items purchased by farmers	
Livestock supplies	69
Crop supplies	344
Machinery and equipment	1,484
Buildings and improvements	625
Family cash living	918
Other expenses	53
Gas, oil and grease	102
Utilities	73
Hired farm labor	3,850
Farm operators (new farms)	5,136
Total full time jobs	22,028

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[1] Includes on project and off project jobs on a national basis.
[2] This loss in jobs is caused by a reduction in wheat production.
* From Bureau of Reclamation, U. S. Department of the Interior - preliminary estimates.

USES OF WATER RESOURCES

Water Resource Development Program

Existing Dams and Reservoirs

Twenty-eight low head dams in South Dakota and 12 in North Dakota have been built across the James River and tributaries (table 8). Two dams are operated and maintained by the U. S. Fish and Wildlife Service to form Sand Lake National Wildlife Refuge. Arrowwood National Wildlife Refuge above Jamestown, North Dakota, includes Arrowwood, DePuy, and Jim Lake Dams. A dam located near the North Dakota-South Dakota State line creates the impoundment of the Dakota Lake National Wildlife Refuge. Huron, South Dakota, constructed two dams across the "Jim" River for its source of water supply. Other dams are used to retain water for livestock, recreation, and other purposes. Isaak Walton and Gurney Dams were partially demolished in 1944 because local residents felt the structures aggravated flood conditions.

Dams have also been constructed across tributary streams. A series of four dams on Elm River and a dam across Willow Creek impound water for Aberdeen municipal supply; Elm Reservoir on Elm River is also used for recreation and wildlife conservation. Turtle Creek Dam on Turtle Creek stores water for fire protection of Redfield, and Lake Mitchell on Firesteel Creek provides Mitchell's water supply and is used extensively for recreation.

Potential Dams and Reservoirs

Return flows from irrigated land in the Crosby-Mohall and Fessenden-Carrington areas or direct diversion from the Missouri River would provide water for lands below Jamestown (figure 3). There are about 100,000 irrigable acres in the upper James and Pipestem Valleys. Potential Jamestown Reservoir would provide storage of water to be released as required for downstream needs. The New Rockford Unit is planned to irrigate 55,000 acres. From Jamestown to LaMoure there are about 10,000 acres of irrigable land along the James River to be served by direct pumping plants. From Oakes, North Dakota, to Columbia, South Dakota, there are approximately 100,000 irrigable acres to be served by pumping from the James River north of Oakes. Because of limited capacity of the James River, offstream storage in the vicinity of Taayer Lake would be provided to meet peak irrigation demands in the Oakes-Columbia area.

Water for Oahe Unit would be pumped from Oahe Reservoir, now under construction on the Missouri River above Pierre, South Dakota, to potential Blunt Reservoir by way of the Pierre Canal. Flow from potential Blunt Reservoir would travel eastward through Ree Canal to Pony Hills Power Drop near Miller, generating 180,000 kilowatts of electrical energy for use in pumping irrigation water to an estimated 750,000 arable acres in the development unit. Scatterwood, Cresbard, Cottonwood, Sand Creek, and Firesteel Regulation Reservoirs are being considered for storage and regulation of irrigation waters (table 9). Return flows, water from the Missouri River, or a combination of both, would be used to serve 160,000 acres in the Yankton-Vermillion area.

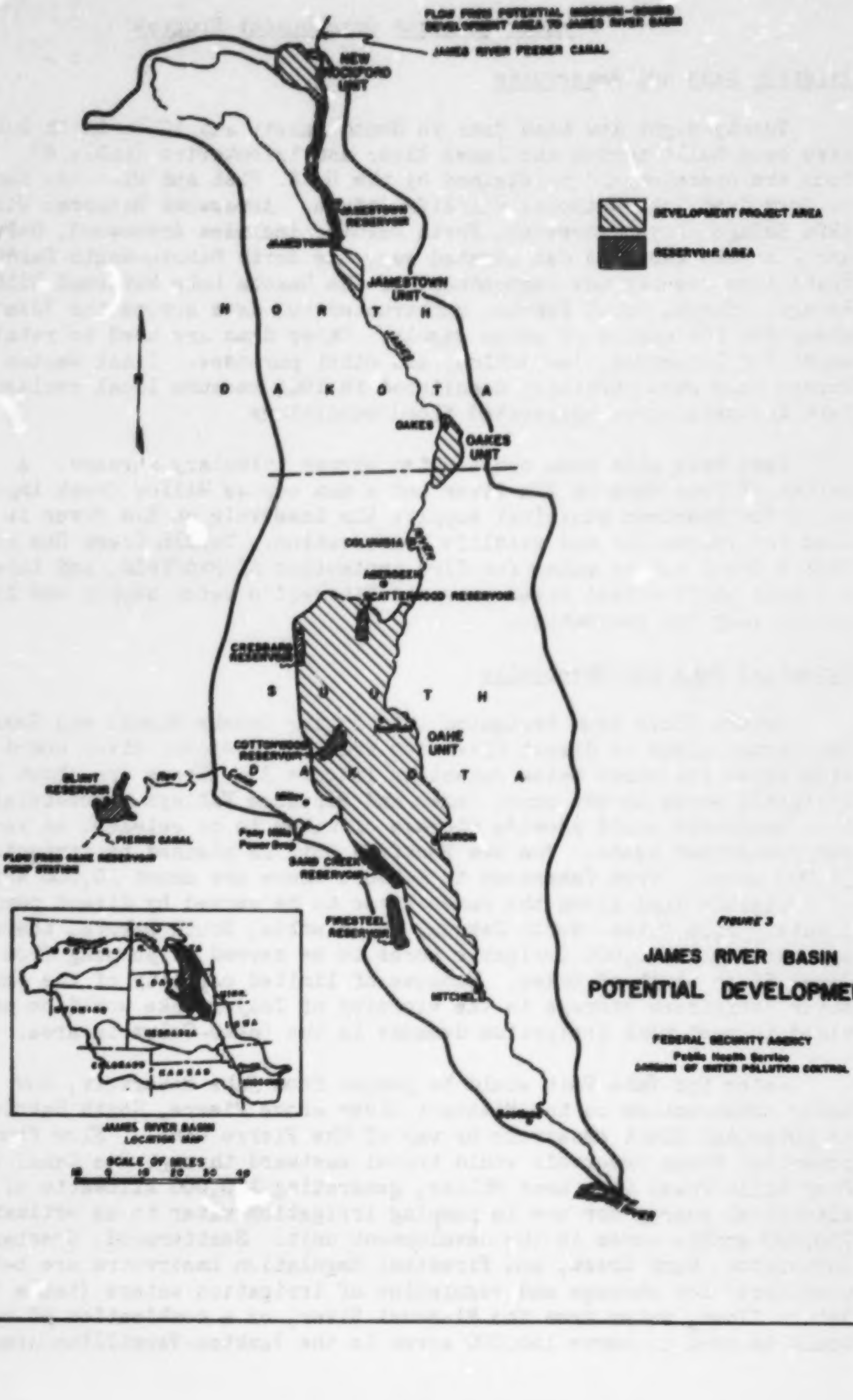

FLOW FROM POTENTIAL MISSOURI-SOURIS DEVELOPMENT AREA TO JAMES RIVER BASIN
JAMES RIVER FEEDER CANAL
NEW ROCKFORD UNIT
JAMESTOWN RESERVOIR
JAMESTOWN
JAMESTOWN UNIT
DEVELOPMENT PROJECT AREA
RESERVOIR AREA
N O R T H
D A K O T A
OAKES
OAKES UNIT
COLUMBIA
ABERDEEN
SCATTERWOOD RESERVOIR
CRESBARD RESERVOIR
S O U T H
D A K O T A
OAHE UNIT
COTTONWOOD RESERVOIR
BLUNT RESERVOIR
PIERRE CANAL
FLOW FROM OAHE RESERVOIR PUMP STATION
Miller
Pony Hills Power Drop
HURON
SAND CREEK RESERVOIR
FIRESTEEL RESERVOIR
MITCHELL
MONTANA
N. DAKOTA
S. DAKOTA
MINN.
WYOMING
IOWA
NEBRASKA
COLORADO
KANSAS
MISSOURI
JAMES RIVER BASIN LOCATION MAP
SCALE OF MILES
10 0 10 20 30 40

FIGURE 3

JAMES RIVER BASIN

POTENTIAL DEVELOPMENTS

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

Table 8. James River Basin - Existing dams and reservoirs

Unit	Stream	Approximate Miles above mouth Main stem	Tributary
North Dakota			
FERA Dam	James River	700	
Fessenden Dam	James River	696	
Sellie Dam	James River	695	
C.C.C. Dam	James River	685	
FERA Dam	James River	665	
Arrowwood Dam	James River	605	
Jim Lake Dam	James River	597	
De Puy Dam	James River	594	
Bone Hill Creek Reservoir	Bone Hill Creek	528	30
C.C.C. Dam	James River	523	
C.C.C. Dam	James River	506	
Dakota Lake Dam	James River	470	
South Dakota			
Maple River Lake	Maple River	429	45 25
Dam	James River	451	
Dam	James River	442	
Elm Lake	Elm River	429	55
Willow Lake	Willow Creek	429	32
Dam	Elm River	429	27
Dam	Elm River	429	13
Dam	Elm River	429	11
Dam	James River	412	
Dam	James River	259	
Dam	Turtle Creek	292	2
Dam	James River	243	
Dam	James River	223	
Dam	James River	219	
Dam	James River	215	
Dam	James River	195	
Dam	James River	157	
Dam	James River	155	
Dam	James River	142	
Dam	Firesteel Creek	139	5
Dam	James River	139	
Dam	James River	117	
Dam	James River	102	
Dam	James River	83	
Dam	James River	54	
Dam	James River	39	
Dam	James River	24	
Dam	James River	5	

Table 9. James River Basin - Potential reservoir and diversion projects

Reservoir	Stream	Approximate Miles above mouth James River	Tributary
Jamestown	James	578	-
Thayer Regulating Res.	James (offstream)	484	-
Oakes Diversion	James	484	-
Scatterwood	West Branch Snake Creek	300	8
Cresbard (Upper)	West Branch Snake Creek	300	8
Cresbard (Lower)	West Branch Snake Creek	300	8
Burdette	Turtle Creek	290	5
Pony Hills Power Drop	Turtle Creek	290	121
Cottonwood	Cottonwood Lake	290	2
Sand Creek	Sand Creek	176	25
Firesteel (Upper)	Firesteel Creek	139	50
Firesteel (Lower)	Firesteel Creek	139	40

Water Supply

Municipal

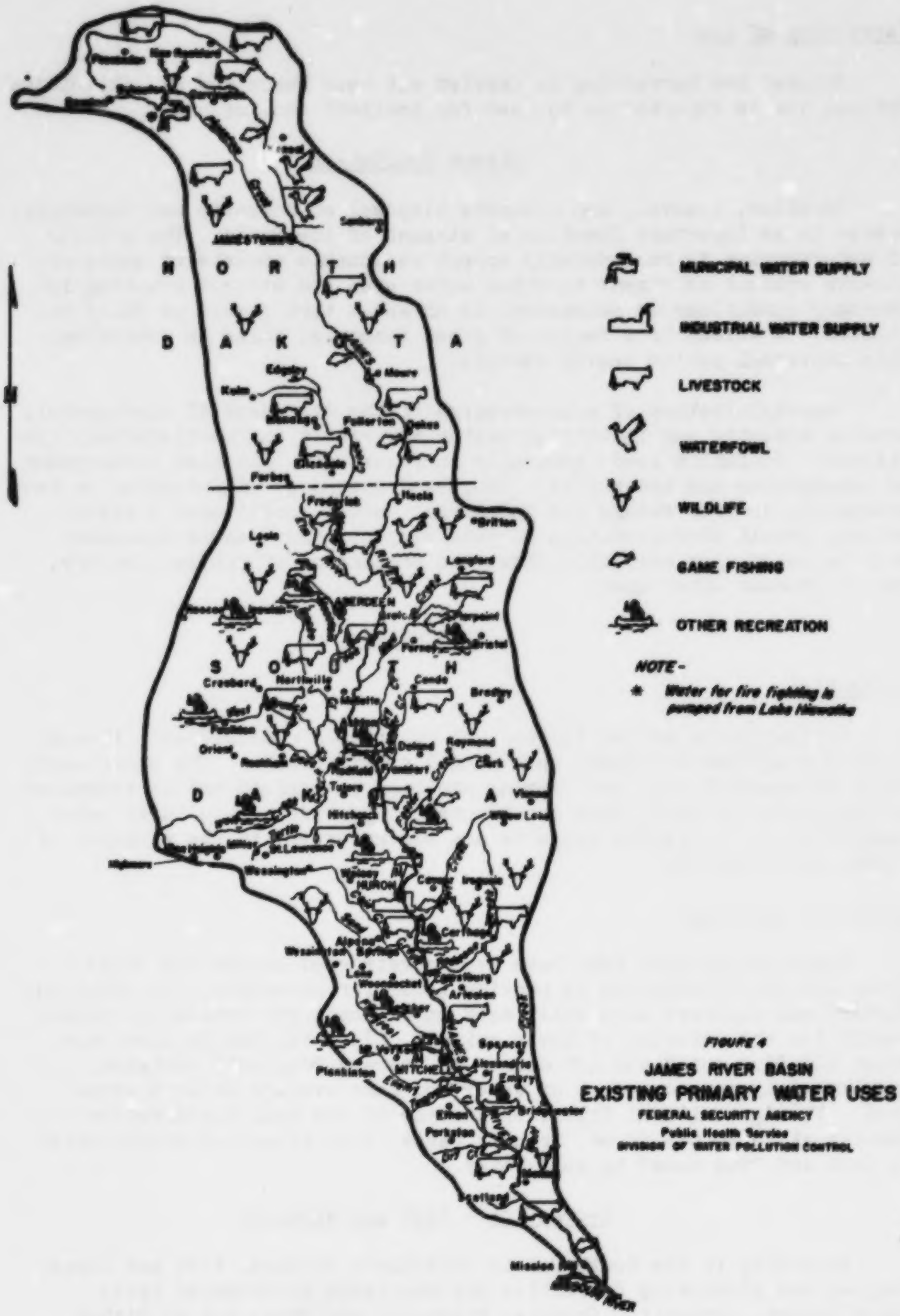
Municipalities in the Basin commonly utilize ground sources for water supply (figure 4). Most wells have good yields; however, ground water levels in some areas have been declining and redrilling of wells has been necessary to insure adequate supplies. Water consumption varies widely; Some communities exceed the 100-gallons per capita daily normally expected and some use only a fraction thereof.

Generally, ground water in the Basin is high in total solids, iron, manganese, sulphates, fluorides, alkalinity, and hardness. Some municipalities have facilities to reduce concentrations of many of these constituents. Water softening and chlorination is practiced at several communities. Iron removal facilities have been installed at Cresbard and Emory, South Dakota. Britton has a defluoridation plant.

Aberdeen, Huron, and Mitchell use surface sources and provide partial softening and chlorination before delivery to consumers. Aberdeen fluoridates its supply.

Industrial

Water use in industry includes processing, cooling, and air conditioning. Water in quantity is utilized in the food processing industry for preparation of meat, dairy products, and dressed poultry. Livestock watering is important--3 to 15 gallons per animal being consumed daily. Use of watering ponds is widespread. Water consumption per 100 pounds of milk, cream, or butter produced varies from 11 to 25 gallons. Meat packing plants may use 6,000 gallons of water per ton of animals processed and poultry dressing establishments may utilize 2,000 gallons for each 1,000 pounds of live birds handled.



MUNICIPAL WATER SUPPLY
INDUSTRIAL WATER SUPPLY
LIVESTOCK
WATERFOWL
WILDLIFE
GAME FISHING
OTHER RECREATION
NOTE -
* Water for fire fighting is pumped from Lake Hiawatha
N
N O R T H D A K O T A
S O U T H D A K O T A
JAMESTOWN
Sanborn
Edgeley
Kulm
Le Moure
Fullerton
Oakes
Ellendale
Forbes
Frederick
Hecla
Britton
Leola
Langford
ABERDEEN
Bristol
Conde
Bradley
Northville
Cresbard
Faulkton
Orient
Redfield
Doland
Raymond
Clark
Tulare
Hitchcock
Vienna
Willow Lake
Miller
St. Lawrence
Highmore
Wessington
Wolsey
HURON
Cavour
Iroquois
Carthage
Alpena
Wessington Springs
Lane
Woonsocket
Forestburg
Artesian
Letcher
Mt. Vernon
Plankinton
MITCHELL
Spencer
Alexandria
Emery
Bridgewater
Ethan
Parkston
Dry Cr.
Scotland
Mission Hill
MISSOURI RIVER

FIGURE 4

JAMES RIVER BASIN
EXISTING PRIMARY WATER USES
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

Harvesting of Ice

Natural ice harvesting is carried out near Huron and at Lake Mitchell. Natural ice is reported to be used for indirect cooling only.

Stream Sanitation

Dilution, removal, and ultimate disposal of domestic and industrial wastes is an important function of streams of the Basin. The ability of watercourses to successfully accept reasonable amounts of waste effluents without detriment to other water uses and without creating insanitary conditions or nuisances, is an asset that should be fully exploited. A stream is a factor of great financial value in rendering this universal public health service.

Overexploitation of a watercourse by the discharge of inadequately treated domestic and industrial wastes may result in unsatisfactory conditions. Pollution loads generally increase with continued development of communities and industries. Increased discharge of untreated or inadequately treated sewage and industrial wastes constitutes a misuse and may result in degradation of receiving streams. Waste treatment must be based upon available flow, the phenomenon of stream recovery, and downstream water uses.

Agriculture

Irrigation

Irrigation is as yet limited and relatively undeveloped. Present farming practices are based upon normal precipitation. The uncertainty which accompanies dry land farming has been recognized and is evidenced by the number of small dams constructed to provide agricultural water. Demonstration irrigation projects are now under way in the vicinity of Huron, South Dakota.

Livestock watering

Numerous low head dams have been constructed across the "Jim" River and its tributaries to provide water for livestock. In addition, farmers and ranchers have built many small ponds for retaining surface runoff for the watering of their animals. In North Dakota there are about 400 "dug-outs" and 450 dams. An average "dug-out" contains approximately one acre-foot of water and dams average about 5 acre-feet. The Agricultural Extension Service of the Soil Conservation Section at Fargo has found, in many cases, that livestock prefer water in dams and "dug-outs" to well water.

Recreation - Fish and Wildlife

According to the South Dakota Department of Game, Fish and Parks, camping and picnicking facilities are available at Richmond Lake; Lakes Louise, Iroquois, Osceola, Mitchell, and Mina; and at Fisher Grove. Picnicking facilities are open to the public at Lakes Wilmarth, Faulkton, and Byron; Huron Memorial Park; and Hickman Dam. Hunting for small game is permitted at Lakes Oaceola, Byron, and Wilmarth; Hickman Dam; Fisher Grove; and Forestburg State Recreational areas. Excellent fishing has been experienced at Lake Louise on Wolf Creek.

In South Dakota, 2,415 acres in the James Basin have been set aside for these recreational pursuits. In addition, there are three national wildlife refuges, one located at Sand Lake in South Dakota and the other two within the Arrowwood Lake and Dakota Lake areas in North Dakota. Small recreational areas near Jamestown include Homer (5 acres), Fred Smith (2 acres), and Spiritwood Lake which is used extensively. The Pipestem Creek area, a short distance above Jamestown, may become important.

Big game in the Basin is limited to antelope and white-tailed deer. Upland game species consist pf pheasants, mourning doves, sharp-tailed grouse, prairie chickens, Hungarian partridges, and cottontails; fur animals include muskrats, jackrabbits, skunks, minks, raccoons, beavers, weasels, badger, and red foxes. The Basin is one of the most important waterfowl migration lanes in the country. Large numbers of blue and snow geese fly along this route each spring. White-fronted and Canada geese use Basin areas during their flights in spring and fall. The marshy areas along the river are used as nesting grounds for several species of ducks. Duck hunting is an important aspect of outdoor recreation in the Basin.

SURVEY METHODS

Studies of stream pollution in the James River Basin included:

(a) Assembly and review of existing information.

(b) Procurement of most recent information regarding: (1) water utilization, (2) sources of pollution, including sewage and industrial waste treatment and discharge.

(c) A sampling and laboratory program to secure various physical, chemical, and bacteriological information on stream conditions in order to correlate actual stream characteristics with sources of pollution.

(d) Limnological surveys to determine the basic character of the river, particular effects of pollution upon aquatic life, and extent of pollutional influences.

(e) A review of development plans to ascertain water routing in order to determine which communities and river reaches may be affected by increased water resources.

(f) Study of existing and probable future water uses as influenced by pollution.

(g) Assembly and evaluation of data.

Field Investigations

Field surveys of water supplies and sources of pollution were conducted by sanitary engineers from the State water pollution control agencies of North Dakota and South Dakota, and by engineers of the Public Health Service detailed to the State health departments.

Water Supply

Water supply data collected for each municipality and industry included: source of supply, treatment, population served, and average consumption. In most cases latest population estimates were employed to arrive at the population served by water systems.

Sources of Pollution

Domestic Sewage--Data gathered for each municipality included the sewered population, degree and type of treatment, and receiving body of water. Percentage B.O.D. removal by treatment plants was assumed to be 35 percent for primary treatment and 75 percent for secondary treatment where records or supplemental information were not available. The judgment and experience of the investigating engineer were depended upon to evaluate treatment processes where inspection indicated exceptionally good results, an overloaded plant, or inefficient or faulty operation.

Industrial Wastes--All industrial establishments (table 10) discharging significant pollutional wastes were investigated to secure information sufficiently detailed to permit a quantitative evaluation of the organic pollutional load in terms of population equivalents. Survey data obtained from industries included the following: type of industry, location, operation (with seasonal variation), water supply, quantity of raw materials, quantity of finished products, volume and character of waste, degree of waste treatment, and receiving body of water.

Table 10. James River Basin - Industrial establishments surveyed

Industry	Number
Dairy Products	41
Packing House	8
Rendering	1
Stockyard	2
Slaughterhouse	3
Poultry Dressing	7
Cream Receiving Station	1
Potato Chip	1
Railroad Roundhouse	2
Locker Plants	24
Total	90

Municipal Population Equivalent--Organic industrial waste is expressed as population equivalents based upon B.O.D. Where industry discharged to municipal systems the population equivalent of industrial wastes was added to that of the sewered population. The waste discharged was the total population equivalent minus that portion removed by treatment.

Stream Evaluation

Sampling Procedure--Stream sampling stations were established above and below sources of known or suspected pollution, in the vicinity of dams or dam sites and diversions, at localities where other water uses might develop, and at appropriate points on important tributaries. In areas where significant pollution was expected intermediate points were added. Conveniently located bridges were utilized for sampling wherever possible. In the absence of bridges, suitable walk-in points were selected.

Sampling was conducted to secure a representative portion of the stream in question, generally at mid-depth from the main channel or channels. A copper depth sampler was employed. Samples were collected for bacteriological and chemical analyses.

The sample collector recorded the time of day to the nearest minute for each sample and the water temperature to the nearest degree centigrade. The sample collector also noted any unusual stream conditions, the presence of possible sources of pollution, and other pertinent information.

All B.O.D. and coliform samples were iced immediately after collection. Oxygen samples were dosed to the free iodine stage in the field except in summer when samples collected at stations below Huron, South Dakota, were iced in the field and dosed upon arrival at the laboratory. Samples were transported to the laboratory within six hours after collection.

Number of Sampling Stations--Winter sampling included 22 stream stations, 7 in North Dakota and 15 in South Dakota. The summer study covered 16 stream locations in South Dakota and 7 in North Dakota.

Limnological Methods--Water samples for both chemical and biological analysis as related to the limnological investigation were collected with a Kemmerer sampler. During the spring season, plankton samples were concentrated in a net of #20 bolting cloth, but early fall samples were centrifuged, since most organisms then present easily passed through meshes of the plankton net. Bottom organisms were collected wherever possible with a Petersen dredge, and with a hand net where rocky bottom prevented use of the dredge. In the latter cases it was not possible to obtain quantitative estimates. Chemical analyses in conjunction with limnological surveys were performed in the field immediately after collection of samples, and were according to the usual methods (American Public Health Association, Standard Methods for the Examination of Water and Sewage, 9th Ed., 1946).

Stream Discharge Data

In order to correlate laboratory results with pollution reaching rivers, stream flow must be secured at times of sampling. These data were obtained through the appropriate State agencies and the U. S. Geological Survey and are included with laboratory data in appendix D.

Laboratory Operations

Laboratory facilities included the North Dakota State laboratory at Bismarck and a South Dakota laboratory established at the Huron, South Dakota, sewage treatment plant. Some samples for chemical analysis were forwarded to the laboratory of the U. S. Geological Survey, Quality of Water Branch, at Lincoln, Nebraska.

Tests and Their Significance

Routine tests included temperature, turbidity, dissolved oxygen, biochemical oxygen demand, pH, alkalinity, phosphate, ammonia, and coliform group organisms. All tests were performed in accordance with the American Public Health Association Standard Methods for Examination of Water and Sewage, (9th Ed. 1946). The significance of these tests is discussed in appendix D.

Definition of Terms

Terms as used throughout this report are defined in appendix D.

PRESENTATION OF DATA

Public Water Supplies

In North Dakota about 24,000 people in 17 communities (figure 5), including the State Hospital at Jamestown, use ground sources for their water supplies and consume over 2.4 million gallons daily (table 11). Sykeston hauls in drinking water obtained from wells in the municipality and the surrounding countryside, and gets water for fire fighting and lawn sprinkling from Lake Hiawatha. At Jamestown the municipality and the State Hospital filter, soften, and chlorinate their water supplies. Edgeley and Oakes chlorinate, and New Rockford filters and chlorinates.

Sixty-three communities in South Dakota (table 11), including a State Hospital at Redfield and a Training School at Plankinton, use ground sources. Ree Heights and Wessington Springs use spring water. A population of about 35,600 uses about 2.1 million gallons daily. Alexandria, Frederick, Highmore, Ipswich, Scotland, Spencer, and Willow Lake employ chlorination; Cresbard and Emery practice iron removal and filtration; and Britton defluoridates its supply.

Aberdeen, Huron, and Mitchell use surface sources to provide approximately 46,000 people and industry (table 12) about 4.0 to 7.0 million gallons of water daily. Raw water is filtered, softened, and chlorinated by these communities; Aberdeen also fluoridates its water supply.

Table 11. James River Basin - Municipal water supplies for small towns

Municipality	Source¹	Treatment²	Population served	Average Consumption M.G.D.	Municipality	Source¹	Treatment²	Population served	Average Consumption M.G.D.
North Dakota					**South Dakota** (cont'd)				
[illegible]	V	N	1,500	[illegible]	Highmore	V	D	1,000	0.060
[illegible]	V	D	800	0.050	Hitchcock	V	N	200	0.010
Ellendale	V	N	1,800	0.150	Ipswich	V	D	1,000	0.035
Fessenden	V	N	650	0.040	Iroquois	V	N	413	0.012
Forbes	V	N	800	0.065	Langford	V	N	456	0.005
Fullerton	V	N	286	0.004	Leola	V	N	772	0.050
Gackle	V	N	600	[illegible]	Lesterville	V	N	185	0.002
Jamestown	V	[illegible]	10,000	0.850	Mansfield	V	N	100	0.001
Jamestown State Hospital	V	[illegible]	2,375	0.500	Mellette	V	N	250	0.013
					Menno	V	N	868	0.040
Kulm	V	N	700	0.050	Miller	V	N	1,902	0.150
LaMoure	V	N	800	0.100	Mission Hill	V	N	165	0.001
Medina	V	N	500	0.085	Mt. Vernon	V	N	400	0.014
Montpelier	V	N	138	0.005	Northville	V	N	178	0.030
New Rockford	V	IR	1,800	0.150	Orient	V	N	200	0.020
Oakes	V	D	1,650	0.200	Parkston	V	N	1,354	0.060
Sykeston	V*	N	250	0.008	Pierpont	V	N	326	0.010
Verona	V	N	150	0.001	Plankinton	V	N	750	0.060
Sub-total			23,589	2.448	Plankinton Tr. School	V	N	90	0.025
South Dakota					Raymond	V	N	178	0.005
Alexandria	V	D	714	0.025	Redfield	V	N	2,655	0.180
Alpena	V	N	500	0.020	Redfield State Hospital	V	N	789	0.070
Andover	V(dug)	N	377	0.006	Ree Heights	S	N	250	0.012
Artesian	V	N	489	-	Rockham	V	N	200	0.005
Ashton	V	N	250	0.006					
Bristol	V	N	547	0.050	Roscoe	V	N	386	0.031
Brentford	V	N	138	0.010	Roswell	V	N	50	0.001
Bridgewater	V	N	748	0.070	St. Lawrence	V	N	175	0.005
Britton	V	Dl	1,430	0.110	Scotland	V	D	1,083	0.050
Carthage	V	N	458	0.020	Spencer	V	D	558	0.025
Cavour	V	N	158	0.003	Stickney	V	N	385	0.050
Claremont	V	N	234	0.020	Tulare	V	N	212	0.008
Clark	V	N	1,497	0.125	Utica	V	N	88	0.005
Conde	V	N	250	0.025	Virgil	V	N	95	0.006
Cresbard	V	DAIR	269	0.013	Wessington	V	N	463	0.020
Doland	V	N	723	0.070	Wessington Spgs.	S	N	1,500	0.150
Emery	V	DAIR	480	0.080	Willow Lake	V	D	484	0.008
Ethan	V	N	319	0.012	Wolsey	V	N	400	0.020
Faulkton	V	N	800	0.040	Woonsocket	V	N	1,400	0.050
Forestburg	V	N	180	0.005					
					Sub-total			35,583	2.133
Farmer	V	N	60	0.004					
Frankfort	V	N	350	0.030	Total			59,172	4.581
Frederick	V	D	408	0.003					
Groton	V	N	1,084	0.080					
Hecla	V	N	500	0.030					

---

¹Source - V - Wells
S - Springs

²Treatment
A - Aeration
F - Coagulation, Sedimentation, Filtration
S - Softening
D - Chlorination
IR - Iron Removal
N - None
Dl - Defluoridation

*At Sykeston, drinking water is hauled in from individual wells in the municipality and the surrounding country. Water for fire-fighting and irrigation is pumped from Lake Hiawatha.

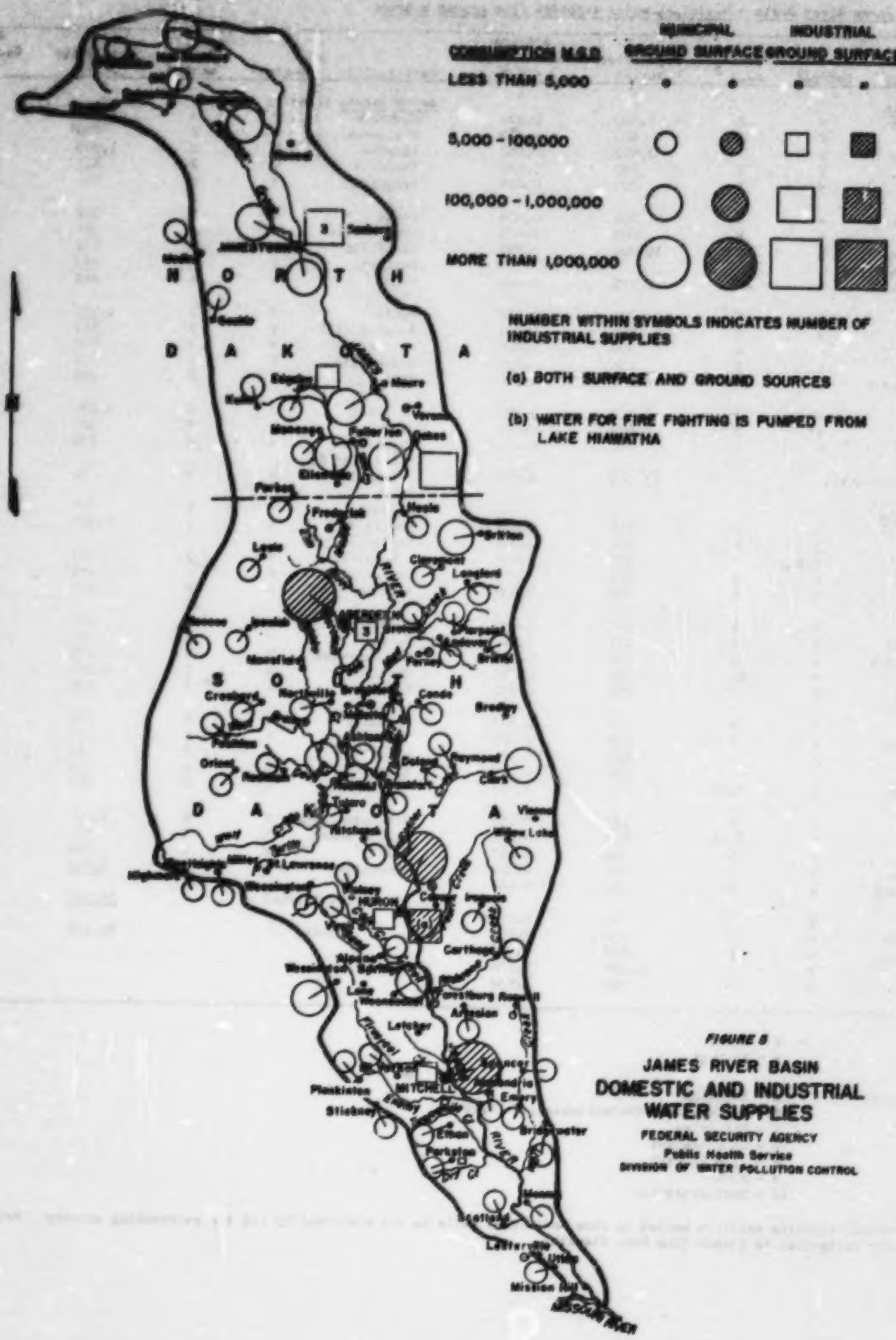

MUNICIPAL
INDUSTRIAL
CONSUMPTION M.G.D.
GROUND SURFACE
GROUND SURFACE
LESS THAN 5,000
5,000 - 100,000
100,000 - 1,000,000
MORE THAN 1,000,000
NUMBER WITHIN SYMBOLS INDICATES NUMBER OF INDUSTRIAL SUPPLIES
(a) BOTH SURFACE AND GROUND SOURCES
(b) WATER FOR FIRE FIGHTING IS PUMPED FROM LAKE HIAWATHA
N
NORTH DAKOTA
SOUTH DAKOTA
JAMESTOWN
3
Edgeley
LaMoure
Kulm
Monango
Fullerton
Oakes
Ellendale
Forbes
Frederick
Hecla
Britton
Leola
Claremont
Langford
ABERDEEN
3
Ipswich
Roscoe
Mansfield
Groton
Andover
Bristol
Ferney
Cresbard
Northville
Conde
Bradley
Redfield
Doland
Raymond
Clark
Orient
Tulare
Hitchcock
Vienna
Willow Lake
Miller
St. Lawrence
Highmore
Wessington
HURON
Cavour
Iroquois
Carthage
Wessington Springs
Woonsocket
Forestburg
Artesian
Letcher
Spencer
Alexandria
Emery
Plankinton
MITCHELL
Stickney
Ethan
Parkston
Bridgewater
Scotland
Lesterville
Utica
Mission Hill
JAMES RIVER
MISSOURI RIVER

FIGURE 8

JAMES RIVER BASIN
DOMESTIC AND INDUSTRIAL
WATER SUPPLIES

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

Table 12. James River Basin - Municipal surface water supplies

		Miles above mouth				
Municipality	State	James River	Tributary	Treatment[1]	Population served	Average consumption M.G.D.
James River						
Elm River		429				
Willow Creek			30			
Aberdeen	S. D.			FDHX	21,011	2.0-3.0
James River						
Huron	S. D.	223	-	FDH	12,713	1.0-2.5
Firesteel Creek						
Mitchell	S. D.	139	5	FDH	12,062	1.0-1.5
Total					45,786	4.0-7.0

[1] Treatment - F - Coagulation, sedimentation, filtration
D - Chlorination
H - Soften
X - Fluoridation

Pollution Contributed to Water Resources

The magnitude and extent of sources of pollution are listed in tables 13 and 14, and shown graphically in figure 6 as municipal and industrial wastes expressed as organic population equivalents.

Two communities in North Dakota discharge untreated wastes to streams; one uses lagoons; two discharge to septic tanks before entry into watercourses; three have primary treatment facilities; and three utilize secondary treatment processes. In South Dakota, 11 municipalities discharge untreated wastes to streams; 11 communities have primary treatment plants in operation; and 16 use secondary treatment facilities.

In the Basin about 89,350 people are connected to sewers; roughly 21,450 in North Dakota and 67,900 in South Dakota. In addition, North Dakota industrial wastes contributed to municipal sewers a population equivalent of about 15,350. Industrial wastes discharged to municipal sewerage in South Dakota vary; wastes average a population equivalent of approximately 71,850 but reach a peak fall and early winter total of about 110,200.

In North Dakota, 18,000 of the total population equivalent of 36,800 are reduced to 6,300 by secondary treatment facilities; 2,800 are reduced to 1,800 by primary treatment; 700 are discharged to lagoons and to land; 4,800 are treated by septic tanks, and 10,500 are discharged to streams without treatment. A reduction of 13,650 population equivalents, or 37 percent, is effected through treatment.

In South Dakota, population equivalents of about 9,100 are discharged without treatment; 9,000 are reduced to 6,200 by primary facilities; and 121,600 are reduced to 40,900 by secondary treatment plants. A 60 percent reduction results from municipal waste treatment in the South Dakota portion of the Basin.

Table 13. James River Basin - Sources of municipal[1] pollution

Name and location of municipality	Miles from mouth: James River	Miles from mouth: Tributary	Sewered population	Estimated untreated waste P.E.[2]	Treatment provided	Adequacy of treatment: Des'g	Adequacy of treatment: Oper.	Population equivalent discharged (estimate)[2]	Project needs	Community action
James River										
Fessenden, N.D.	695		700	700	Lagoons	Sat.	Sat.	0	None	-
New Rockford, N.D.	665		1,800	2,300	P	Unsat.	Unsat.	2,300	NP	Inactive
Kelly Creek	640									
Carrington, N.D.		21	1,900	3,685	S	Sat.	Sat.	900	None	-
Jamestown, N.D.	577		8,900	18,050	S	Unsat.	Unsat.	4,800	NP	Planning initiated
Jamestown State Hosp.,N.D.	577		2,375	2,375	S	Sat.	Sat.	600	None	-
Beaver Creek	555									
Gackle, N.D.		50	500	500	P	Sat.	Sat.	325	None	-
LaMoure, N.D.	506		850	2,170	N	-	-	2,170	NP	Inactive
Oakes, N.D.	464		1,420	8,320	N	-	-	8,320	NP	Inactive
Elm River	425									
Maple River		45								
Kulm, N.D.		70	500	660	P	Sat.	Sat.	430	None	-
Edgeley, N.D.		65	800	1,610	P	Unsat.	Unsat.	1,050	A	Inactive
Ellendale, N.D.		15	1,900	2,480	ST	Unsat.	Sat.	2,250	A	Inactive
Frederick, S.D.		5	400	810	N	-	-	810	NP	Inactive
Moccasin Creek	378									
Foot Creek		43								
Leola, S.D.		67	750	750	P	Unsat.	Unsat.	750	R	Inactive
Aberdeen, S.D.		43	18,000	20,520	S	Sat.	Sat.	5,100		-
Mud Creek	338									
Britton, S.D.		70	1,070	1,460	P	Unsat.	Unsat.	910	A	Inactive
Bristol, S.D.		65	600	3,820	S	Sat.	Sat.	950	None	-
Pierpont, S.D.		48	215	215	P	Sat.	Sat.	140	None	-
Andover, S.D.		43	225	225	N	-	-	225	NP	Inactive
Groton, S.D.		36	1,060	1,800	N	-	-	1,800	NP	Planning initiated
Snake Creek	300									
Ipswich, S.D.		90	945	945	S	Sat.	Sat.	260	None	-
West Branch		10								
Faulkton, S.D.		65	750	750	N	-	-	750	NP	Inactive
Turtle Creek	252									
Highmore, S.D.		120	1,200	1,200	N	-	-	1,200	NP	Inactive
Miller, S.D.		95	1,470	2,350	S	Sat.	Sat.	600	None	-
St. Lawrence, S.D.		90	350	350	P	Sat.	Sat.	230	None	-
Redfield, S.D.		2	2,200	2,950	S	Unsat.	Unsat.	1,200	A	Planning initiated
Redfield (school),S.D.		2	830	830	S	Sat.	Sat.	210	None	-
Foster Creek	248									
Clark, S.D.		47	1,400	2,170	S	Sat.	Sat.	435	None	-
Doland, S.D.		36	500	500	N	-	-	500	NP	Inactive
Huron, S.D.	222		12,000	48,700-(81,000)[3]	S	Sat.[4]	Sat.	8,600-(16,400)[3]	E	Inactive
Cain Creek	214									
Wessington, S.D.		63	565	565	S	Unsat.	Unsat.	565	R	Inactive
Wolsey, S.D.		41	400	400	N	-	-	400	NP	Inactive
Pearl Creek	212									
Marsh Creek		5								
Iroquois, S.D.		27	390	390	P	Unsat.	Unsat.	310	E	Inactive
Redstone Creek	188									
Willow Lake, S.D.		90	480	480	P	Sat.	Sat.	310	None	-
Carthage, S.D.		37	340	340	P	Sat.	Sat.	220	None	-
Woonsocket, S.D.	177		1,000	1,580	N	-	-	1,580	NP	Inactive
Tributary	170									
Artesian, S.D.		10	420	610	N	-	-	610	NP	Inactive
Firesteel Creek	139									
Wessington Springs, S.D.		90	1,450	2,850	S	Unsat.	Sat.	2,150	E	Inactive
Mitchell, S.D.	138		12,000	37,000	S	Unsat.	Sat.	18,500	A	Inactive
Enemy Creek	131									
Plankinton, S.D.		67	735	735	P	Sat.	Sat.	475	A	Inactive
Plankinton Tr.Sch.,S.D.		66	100	100	S	Sat.	Sat.	25	None	-
Mt. Vernon, S.D.		60	380	380	N	-	-	380	NP	Inactive
Pierre Creek	124									
Alexandria, S.D.		6	600	1,510	P	Unsat.	Unsat.	980	A	Inactive
Twelve Mile Creek	100									
Pony Creek		2								
Parkston, S.D.		16	1,330	2,345	P	Unsat.	Unsat.	1,520	A	Inactive
Wolf Creek	83									
Spencer, S.D.		47	550	550	S	Sat.	Unsat.	360	Improved operation	-
Emery, S.D.		32	450	450	P	Sat.	Unsat.	360	Improved operation	-
Bridgewater, S.D.		23	700	840	N	-	-	840	NP	Inactive
Dawson Creek	33									
Scotland, S.D.		6	1,225	3,415	S	Sat.	Unsat.	1,350	Improved operation	-
Tributary	25									
Menno, S.D.		6	825	1,275	S	Unsat.	Sat.	600	E	Inactive
Totals			89,350	176,550*				79,350*		

[1] Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers or other population centers.

[2] Includes industrial wastes discharged into municipal sewerage systems.

[3] Including seasonal wastes.

[4] Plant operates satisfactorily under normal loading. Under heavier fall and early winter industrial discharges, plant efficiency may be greatly reduced.

*Peak seasonal wastes increase this total to population equivalent of 214,850 untreated and P.E. of 87,150 discharged.

Note:
NP - New plant
A or E - Additions or Enlargements
R - Replacement

S - Secondary
P - Primary
N - None
ST - Septic Tank

Table 14. James River Basin - Sources of industrial pollution - Industries discharging directly to watercourse

Name and location of industries	Miles from mouth James River	Miles from mouth Tributary	Type of industry	Type of waste produced	Population equivalent (B.O.D.) of untreated wastes	Treatment or other pollution control measures Degree	Treatment or other pollution control measures Adequacy	Population equivalent (B.O.D.) discharged to watercourse	Pollution abatement measures needed[1]	Project status
James River										
Kelly Creek	640		Food and kindred products							
Carrington Sausage Co.		21		Organic	300	Minor	Adequate	(300)[a]	None	-
Neil's Meat Market Carrington, N.D.		21	"	Organic	230	Cesspool	Adequate	-	None	-
Pipestem Creek	578									
Stock Sales Co.		2	"	Organic	400	None	-	400	NP	Inactive
Orleans Canning Co. Jamestown, N.D.		1	"	Organic	6,500	Lagoon[c]	Inadequate	-[b]	NP	Plans approved
Jamestown R.R. Shop Jamestown, N.D.	577		Misc.	Organic & inorganic	100	None	-	100	NP	Inactive
Moccasin Creek	378									
Foot Creek		43	Food and kindred products							
Langan Packing Co.		4		Organic	780	None	-	(780)[c]	NP	Inactive
Torigian Produce Co.		4	"	Organic	130	None	-	(130)[c]	NP	Inactive
N.W. Packing Co. Aberdeen, S.D.		4	"	Organic	1,325	None	-	(1,325)[a]	NP	Inactive
Turtle Creek	292									
Jergies Custom Butchering Redfield, S.D.		6	"	Organic	90	Cesspool	Adequate	-	None	-
Lampee Packing Co. Huron, S.D.	221		"	Organic	430	None	-	430	NP	Inactive
Tributary	137									
Wylan Meat Co. Mitchell, S.D.		2	"	Organic	835	None	-	(835)[a]	NP	Inactive
Tributary	136									
Mitchell Packing Co. Mitchell, S.D.		1	"	Organic	2,290	None	-	(2,290)[a]	NP	Inactive
Twelve Mile Creek	97									
Ethan Dairy Products Ethan, S.D.		20	"	Organic	190	Minor	Inadequate	(190)[a]	NP	Inactive
S. Fork Twelve Mile Creek		4								
Dimock Dairy Products Dimock, S.D.		13	"	Organic	280	Minor	Inadequate	(280)[a]	NP	Inactive
Totals					13,880			7,060		
Total generally reaching watercourse								930		

---

[1] NP - New plant.

[a] Discharge to intermittent stream - reaches watercourse only during high water.

[b] Existing lagoons treat 6,500 population equivalents; overflow in wet weather periods and nuisance conditions occur.

[c] Discharge to slough - drainage to watercourse indefinite or nonexistent and primarily of local significance.

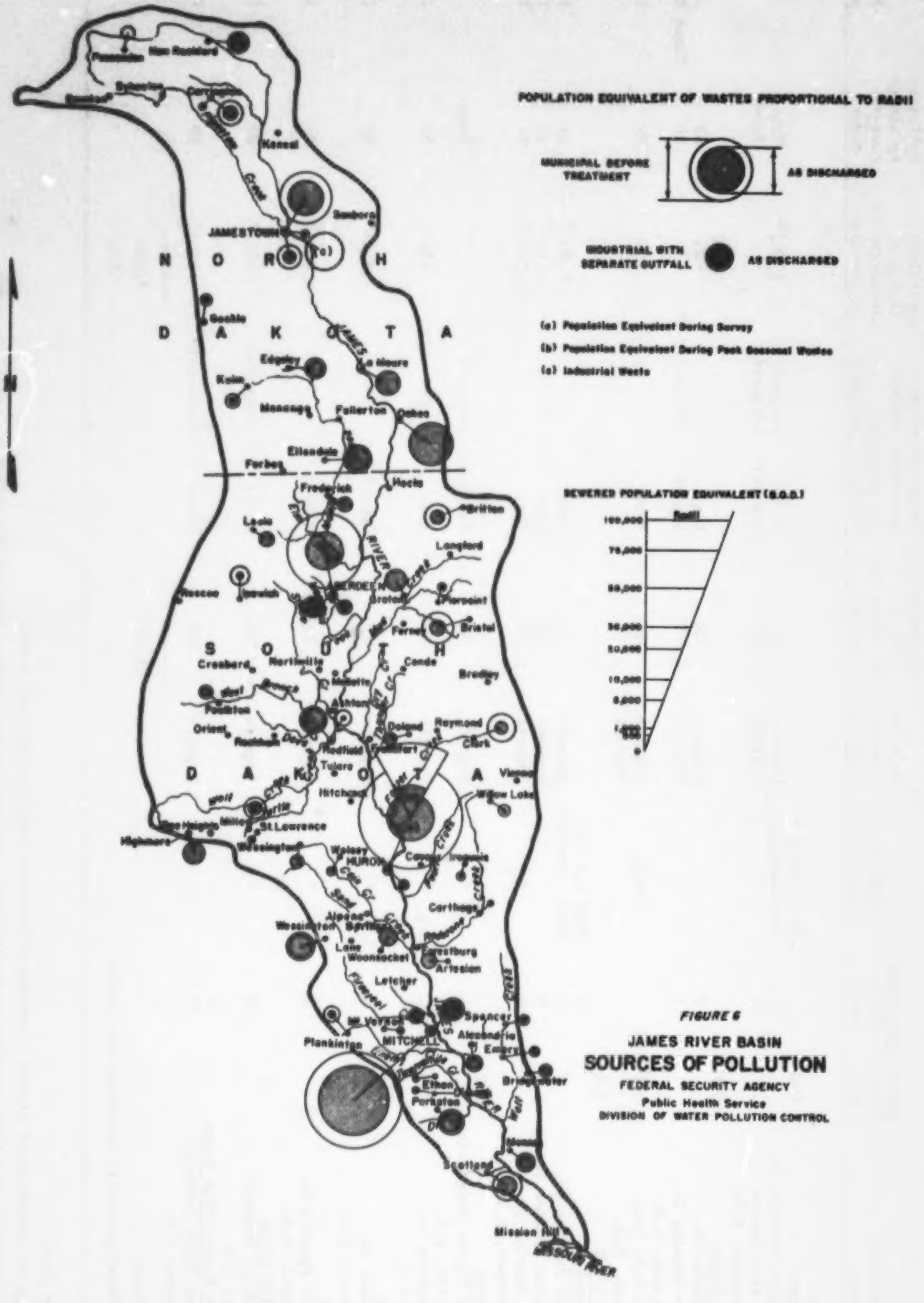

POPULATION EQUIVALENT OF WASTES PROPORTIONAL TO RADII
MUNICIPAL BEFORE TREATMENT
AS DISCHARGED
INDUSTRIAL WITH SEPARATE OUTFALL
AS DISCHARGED
(a) Population Equivalent During Survey
(b) Population Equivalent During Peak Seasonal Wastes
(c) Industrial Waste
SEWERED POPULATION EQUIVALENT (B.O.D.)
Radii
100,000
75,000
50,000
30,000
20,000
10,000
5,000
1,000
500
0
N
NORTH DAKOTA
SOUTH DAKOTA
JAMES RIVER
MISSOURI RIVER
New Rockford
Carrington
Kensal
JAMESTOWN
Sanborn
(c)
Gackle
Edgeley
Kulm
La Moure
Monango
Fullerton
Oakes
Ellendale
Forbes
Frederick
Hecla
Britton
Leola
Langford
ABERDEEN
Roscoe
Ipswich
Groton
Pierpoint
Ferney
Bristol
Cresbard
Northville
Conde
Bradley
Faulkton
Ashton
Orient
Doland
Raymond
Redfield
Frankfort
Clark
Tulare
Vienna
Hitchcock
Willow Lake
Miller
St Lawrence
Highmore
Wessington
Wolsey
HURON
Cavour
Iroquois
Carthage
Alpena
Wessington Springs
Lane
Woonsocket
Forestburg
Artesian
Letcher
Mt Vernon
Spencer
Plankinton
MITCHELL
Alexandria
Emery
Bridgewater
Ethon
Parkston
Scotland
Mission Hill

FIGURE 6

JAMES RIVER BASIN

SOURCES OF POLLUTION

FEDERAL SECURITY AGENCY

Public Health Service

DIVISION OF WATER POLLUTION CONTROL

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A Basin total population equivalent of 176,550 is reduced to 79,350, or 55 percent, by existing treatment plants. Thirty-five communities, or 73 percent of the municipalities in table 13, have treatment facilities. This compares well with a national average of about 61 percent.

Industries discharging to municipal sewers upon which the data are based operate throughout the year and include dairy products processing, poultry dressing, meat packing, and other miscellaneous plants. Seasonal operation of a large packing plant in the Basin is indicated in table 13, but has not been included in percentage computations.

Industries discharging through separate waste outlets are listed in table 14. Thirteen of the 14 separate sources of industrial pollution discharge organic wastes; a railroad maintenance shop has organic and inorganic wastes. The three largest sources of industrial organic pollution are horse meat packing plants. Seven of the remaining plants process meat and three are dairy products plants. Three sources regularly discharge untreated waste to watercourses; two adequately dispose of wastes in cesspools, eight discharge to intermittent creeks or sloughs, and one uses lagoons. Treatment is provided by six industries.

Dissolved Oxygen

In winter of 1951 supersaturation occurred under ice cover at four localities (figure 7). Collections made by the South Dakota State Department of Health during late winter of 1950 and 1952 showed very low oxygen content of water at some points where supersaturation existed in February 1951. Conditions during 1951 are not believed to be generally characteristic of the James. The tie-in of photosynthesis with the supersaturated condition may be assumed. Pre-dawn and mid-afternoon sampling at six stations on February 10 and 11, 1951, in the region of Huron showed a definite oxygen build-up during daylight hours. Ice cover at the six stations, varying from 6 to 24 inches thick, was opaque and covered by about one inch of snow. Results of these special analyses, shown in the following table, indicate photosynthetic activity.

Table 15. James River Basin - Oxygen variation due to photosynthesis

Station	Location	Oxygen Content Early A. M.	Oxygen Content Mid-afternoon
1	4th St. Bridge Huron	15.9 ppm.	18.5 ppm.
2	Just above dam at Hwy. U. S. 14	22.4	23.8
3	Just below dam U. S. Hwy. 14	18.5	20.4
4	Just above sewer outfall	11.7	12.3
5	Just below sewer outfall	-	5.0
6	Bridge 1 mi. below sewer outfall	2.4	7.4

Analysis of plankton samples taken at the same times showed a concentration of photosynthetic organisms amounting to 150 per ml., with Peridinium sp. and Euglena spp. the dominant organisms.

Above Huron stream oxygen content was quite low, typical for a shallow, organic loaded stream under ice cover. Discharge from the Huron sewage disposal plant lowered oxygen from supersaturation to around 5 ppm. while reduction occasioned by sewage discharge at Mitchell was sufficient to cause the dissolved oxygen to be less than 5 ppm. for a short distance. Recovery to supersaturation occurred below both Mitchell and Huron (figure 7).

In North Dakota dissolved oxygen values were below 5 ppm. from the environs of Jamestown to LaMoure, 5.4 ppm. near Oakes, and 0.5 ppm. west of Ludden. During the sampling period, a discharge of 20 c.f.s. at the North Dakota-South Dakota line was reduced to zero in Sand Lake.

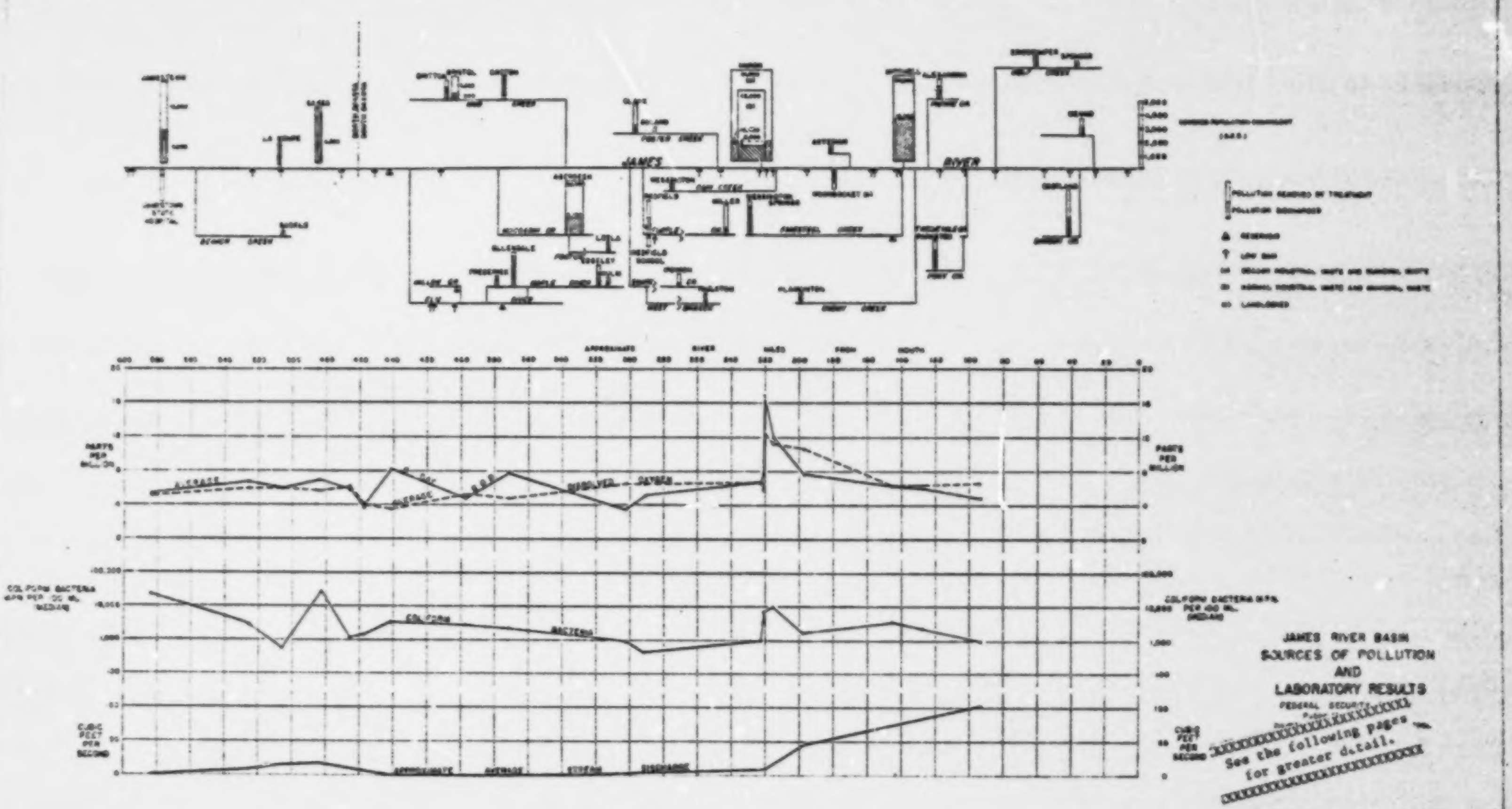
Oxygen supplies were generally adequate in lower reaches of the James in February, 1951, but late winter sampling in 1950 and 1952 indicates that 1951 winter conditions were exceptional and that oxygen levels near zero may be expected under ice cover during some winters.

In early spring, while ice cover was breaking, oxygen concentration was above the critical range (5.0 ppm.) over all the South Dakota stretch (figure 8-A). Unbroken ice cover still endured over long reaches of the stream, but surface runoff had diluted all water that had remained in the stream over winter. Margins of Sand Lake were ice free, and there a supersaturated condition arose through photosynthetic activity.

In summer, amounts of oxygen in solution were uniformly above 5.0 ppm., except at Hecla, South Dakota and at river mile 442, where 4.0 and 3.5 ppm., respectively, were recorded.

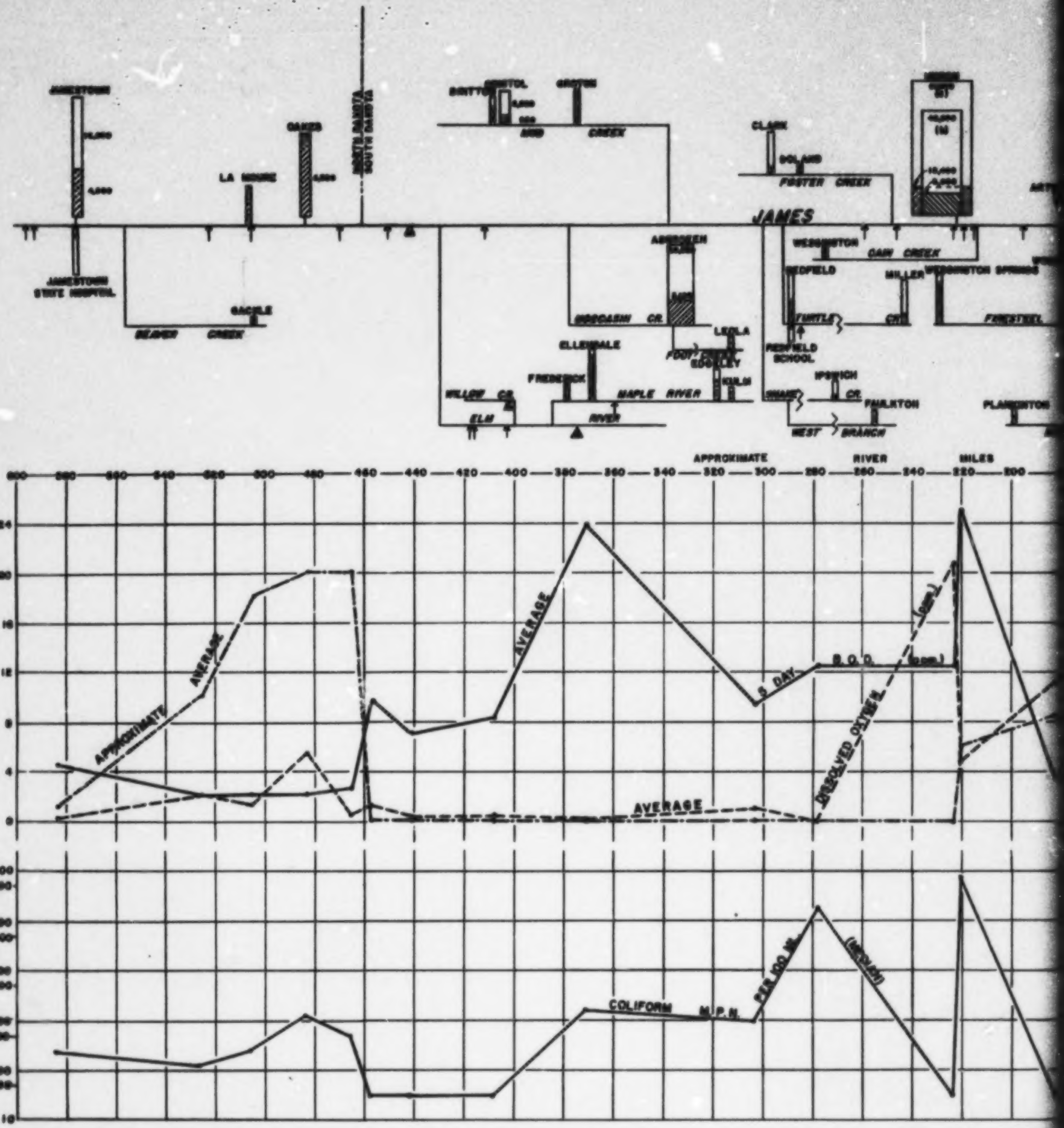
In early fall, 1951, when practically no discharge occurred in the South Dakota reach of the river above Huron, the oxygen picture was generally one of supersaturation. Levels below 100 percent saturation were present only at Lower Sand Lake Refuge, just above Huron, and for a short distance below the Mitchell sewer outfall. In only the last instance were levels depressed to a critical point, and even there were not consistently below 5.0 ppm. The supersaturated condition over most of the river bespoke considerable photosynthetic activity, which had its greatest influence in Upper Sand Lake, just below the sewer outfall at Huron, and again a few miles below the entrance of Mitchell sewage. Nutrient content along most of the river was sufficient to encourage dense plankton growth and so give generally high oxygen levels. Oxygen depression below Mitchell was caused by discharge of a septic effluent from the greatly overloaded sewage treatment plant. The relatively stable effluent discharged at Huron stimulated plankton growth immediately upon entrance into the river.

FIGURE 9



JAMES RIVER BASIN
SOURCES OF POLLUTION
AND
LABORATORY RESULTS

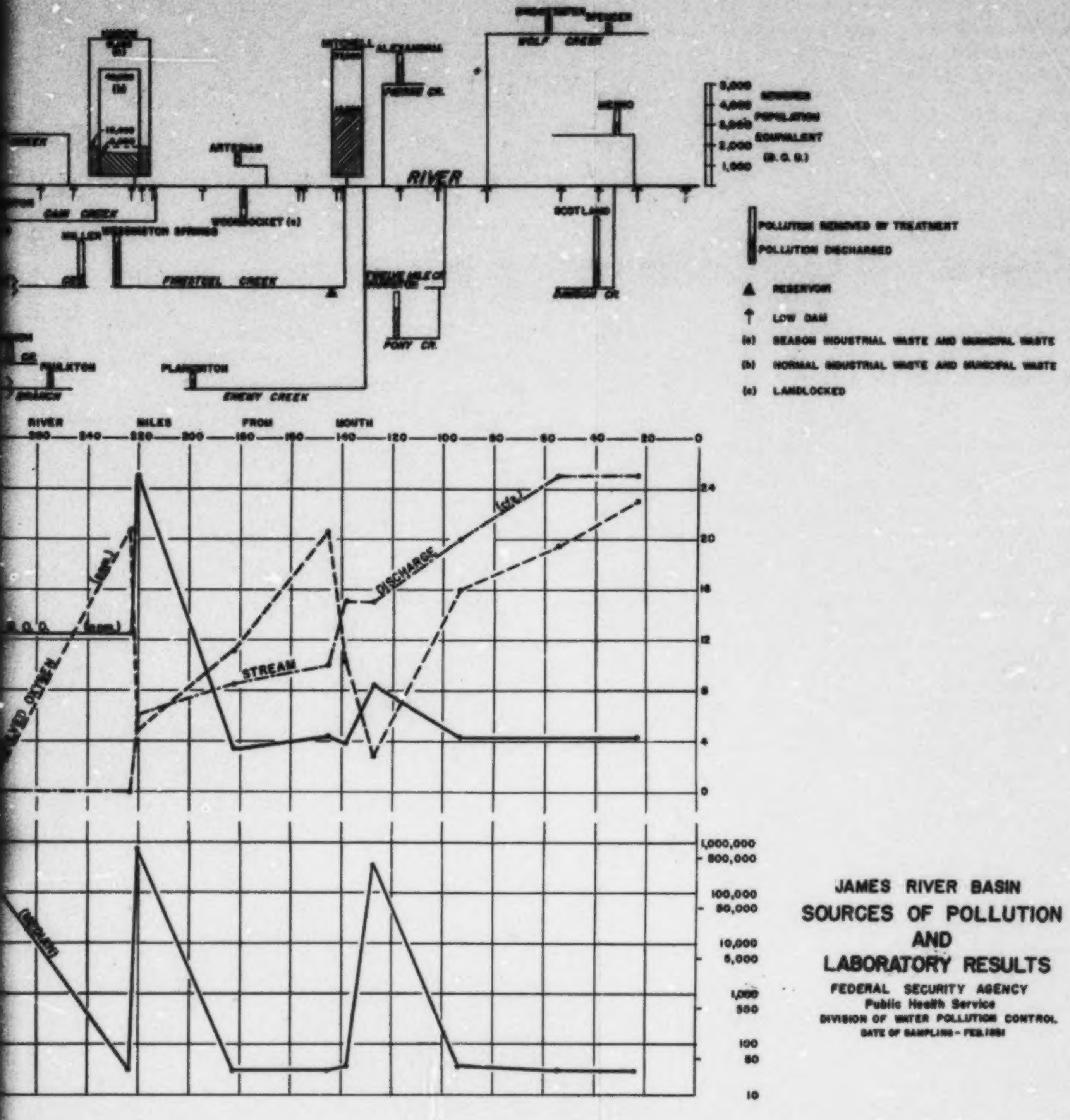
FEDERAL SECURITY XXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX
See the following pages
for greater detail.
XXXXXXXXXXXXXXXXXXXXXXXXXXXX



JAMESTOWN
JAMESTOWN STATE HOSPITAL
LA MOURE
OAKES
NORTH DAKOTA
SOUTH DAKOTA
BEAVER CREEK
GACKLE
BRITTON
BRISTOL
GROTON
MUD CREEK
WILLOW CR.
ELM RIVER
FREDERICK
ELLENDALE
MAPLE RIVER
ABERDEEN
MOCCASIN CR.
LEOLA
FOOT CREEK
EDGELEY
KULM
JAMES
CLARK
DOLAND
FOSTER CREEK
WESSINGTON
DAW CREEK
REDFIELD
TURTLE CR.
REDFIELD SCHOOL
MILLER
WESSINGTON SPRINGS
FIRESTEEL
SNAKE CR.
IPSWICH CR.
FAULKTON
WEST BRANCH
PLANKINTON
(S)
(N)
10,000
APPROXIMATE RIVER MILES
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
24
20
16
12
8
4
0
APPROXIMATE AVERAGE
AVERAGE 5 DAY B.O.D. (ppm)
DISSOLVED OXYGEN (ppm)
AVERAGE
1,000,000
500,000
100,000
50,000
10,000
5,000
1,000
500
100
50
10
COLIFORM M.P.N. PER 100 ML (MEDIAN)

'B

FIGURE 7



JAMES RIVER BASIN
SOURCES OF POLLUTION
AND
LABORATORY RESULTS

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL
DATE OF SAMPLING - FEB.1951

37-a

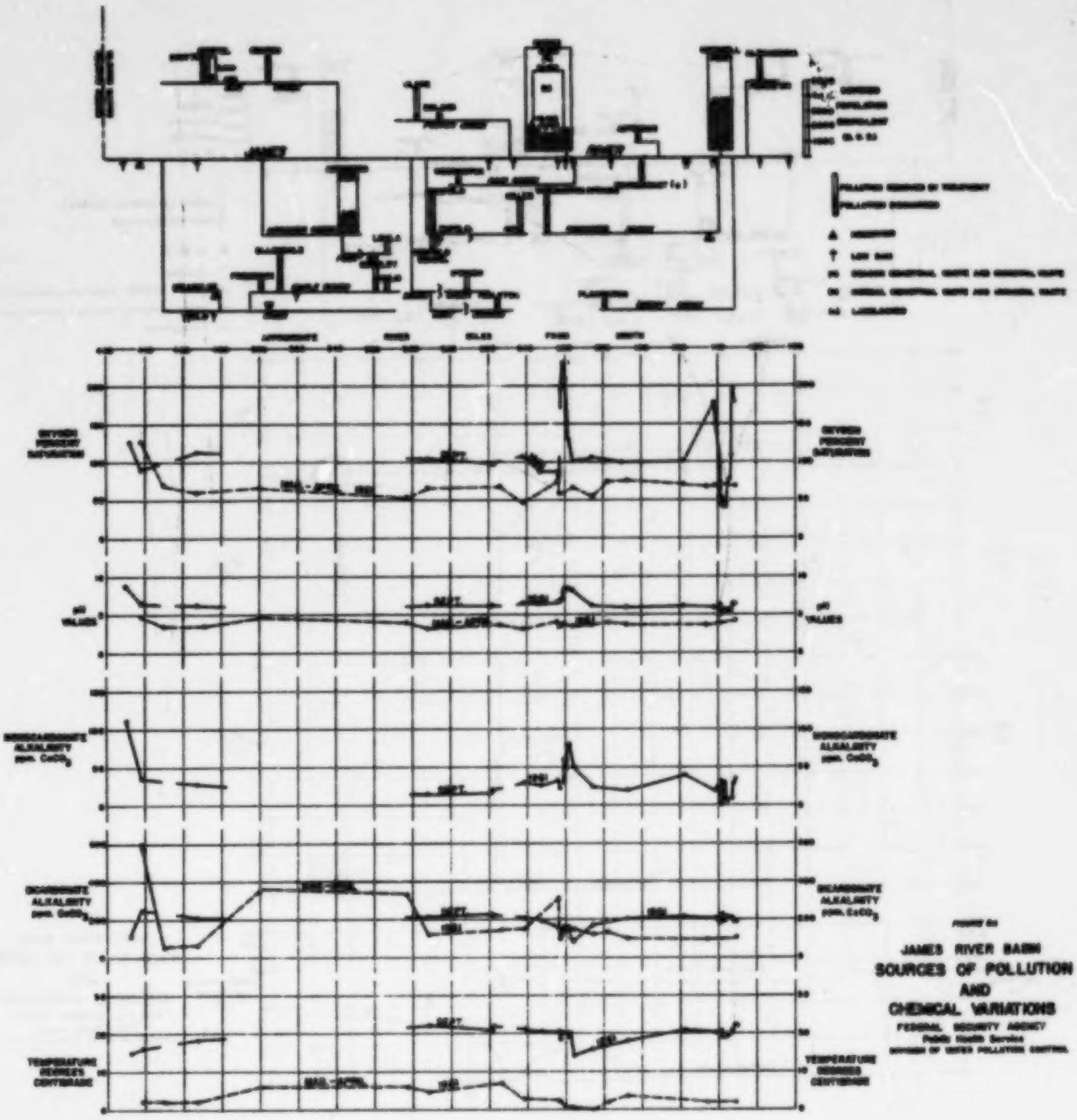
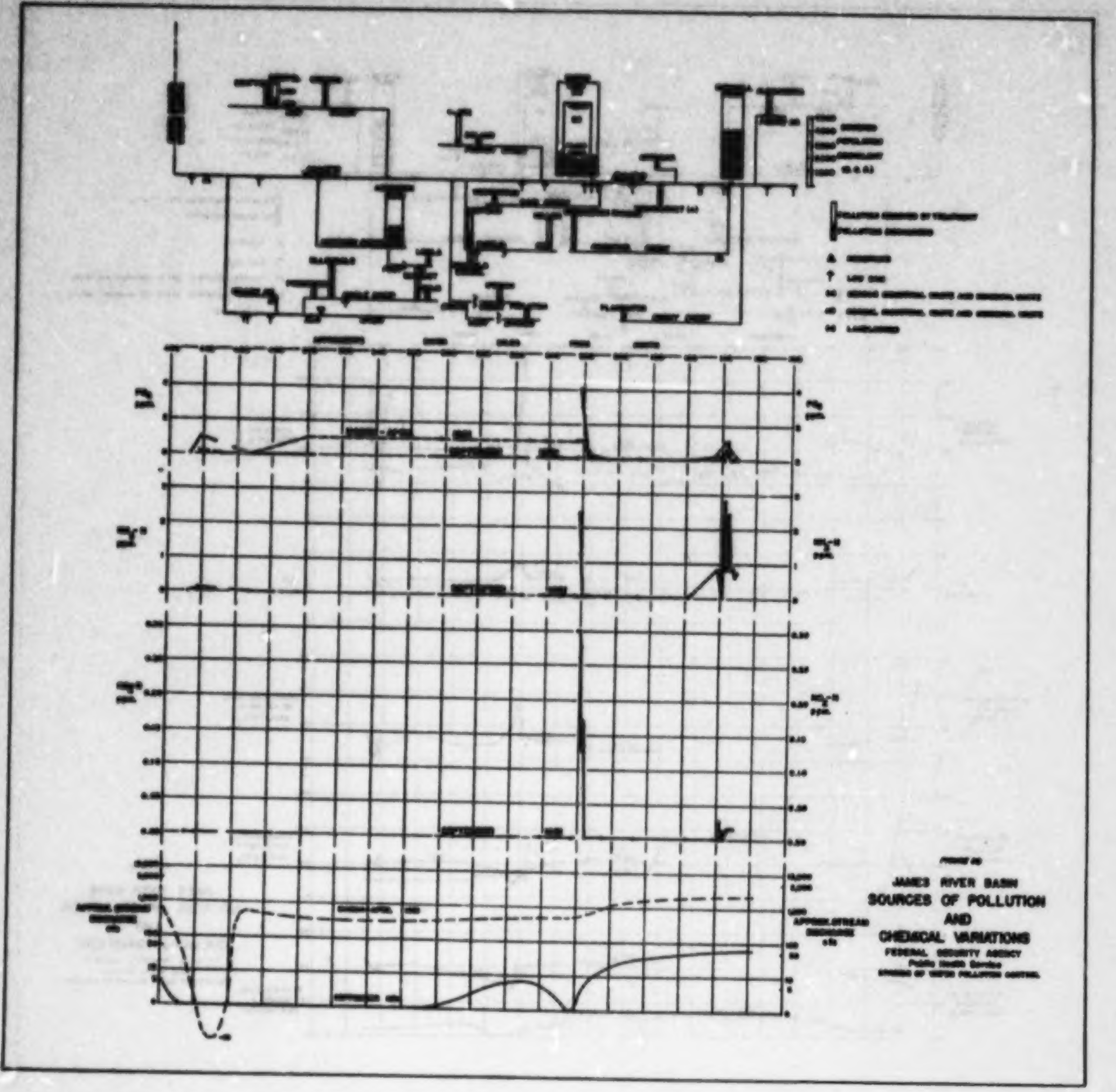


FIGURE [illegible]

JAMES RIVER BASIN
SOURCES OF POLLUTION
AND
CHEMICAL VARIATIONS

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL



JAMES RIVER BASIN
SOURCES OF POLLUTION
AND
CHEMICAL VARIATIONS
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

Biochemical Oxygen Demand

Two series of B.O.D. evaluations of the stream, one in winter and one in late summer, each covering a five-day period, were conducted in 1951.

During the winter sampling period, average B.O.D. concentrations in excess of 20 ppm. occurred at river mile 372, a short distance below the mouth of Moccasin Creek which receives sewage from Aberdeen, and at a point about one and one-half miles below the sewer outfall at Huron. Sharp decreases were evident below each of these points. The average in the river at a point 10 miles below the Mitchell sewer outfall was 8 ppm. (figure 7). Average concentrations in the neighborhood of 10 ppm., a considerable rise above levels noted in the North Dakota section, occurred in South Dakota above Huron. The upper South Dakota reach was devoid of discharge, whereas flows up to 20 second-feet were present in North Dakota (figure 8-A).

During spring of 1951 open water extended from Sand Lake to a short distance below Moccasin Creek. Decreased velocity caused by ice cover below open stretches may result in an increased annual deposition of suspended solids in that locality. Moccasin Creek is in reality a very slow flowing slough when it has a measurable discharge and could hardly be expected to carry a heavy load of suspended solids the distance of 43 miles from Aberdeen to the James River. The coliform density, although low, was indicative of light fecal contamination, but it seems unlikely that wastes from Aberdeen alone could account for the high B.O.D. in the James River below Moccasin Creek. With the exception of the sharp increase at Moccasin Creek, B.O.D. was uniformly high between Sand Lake and Huron. This condition cannot be judged unusual in still, shallow, ice covered water over a rich organic bottom. Lower levels of B.O.D. in the North Dakota reach and below peaks at Huron and Mitchell possibly reflected influences of current, which prevented complete stagnation. About 12 miles below the mouth of Turtle Creek, the recipient of Redfield sewage, a high coliform density was suggestive of fecal contamination, although B.O.D. was not above the general level prevailing in that region. High coliform concentration occurred also at Huron and Mitchell, indicating the role of sewage in high B.O.D. levels at those localities.

The late summer B.O.D. picture (figure 9) was greatly influenced by very high plankton densities. Plankton organisms, while producing high oxygen levels by photosynthesis during daylight hours, consume oxygen in the absence of light. Their respiration and decomposition exert a very considerable demand upon supplies of oxygen contained in sample bottles placed in darkened incubators. B.O.D. occasioned by large numbers of plankters may usually be recognized by the fact that high oxygen levels prevail at the same location or locations. It is not uncommon under such conditions to find oxygen levels in the range of 200 percent saturation associated with B.O.D. amounting to 25 to 30 ppm.

It appears that late summer B.O.D. levels were, with one exception, influenced by a concentrated plankton population. The exceptional case was just below entrance of the Mitchell sewage effluent. This effluent, discharged to a small creek about one and one-half miles above the river, was septic at the time it reached the latter stream in which it flowed along the right bank. It was observed to affect water of not more than one half the stream width and gradually faded out without closely approaching the left bank. B.O.D. of water affected by this effluent was 28 ppm. a short distance below the tributary creek. At Huron, even just below the treatment plant, high B.O.D.'s were coincident with high oxygen levels, indicating influences of plankton algae.

Data of previous surveys included in the Summary of Individual Results, appendix D, provided by the North Dakota State Department of Health, show dissolved oxygen contents of 0.0 ppm. and B.O.D. values of 5.0 ppm. or greater in samples collected in the river reach from Adrian to Ludden, North Dakota. Information compiled by the South Dakota State Department of Health showed depleted dissolved oxygen conditions from Frankfort to a point below Huron. At Forestburg surface runoff to the river raised the dissolved oxygen to 7.3 ppm. in the period March 21-23, 1950.

Coliform Organisms

Coliform densities of 28,000 M.P.N. per 100 ml. at river mile 476 (below the outfall sewer of Oakes, North Dakota) indicated fecal contamination. M.P.N.'s of 3,500 per 100 ml., 7,300 per 100 ml., and 9,300 per 100 ml., in the vicinity of Huron indicated contribution of domestic wastes to the river at a point immediately below the Huron water supply dam.

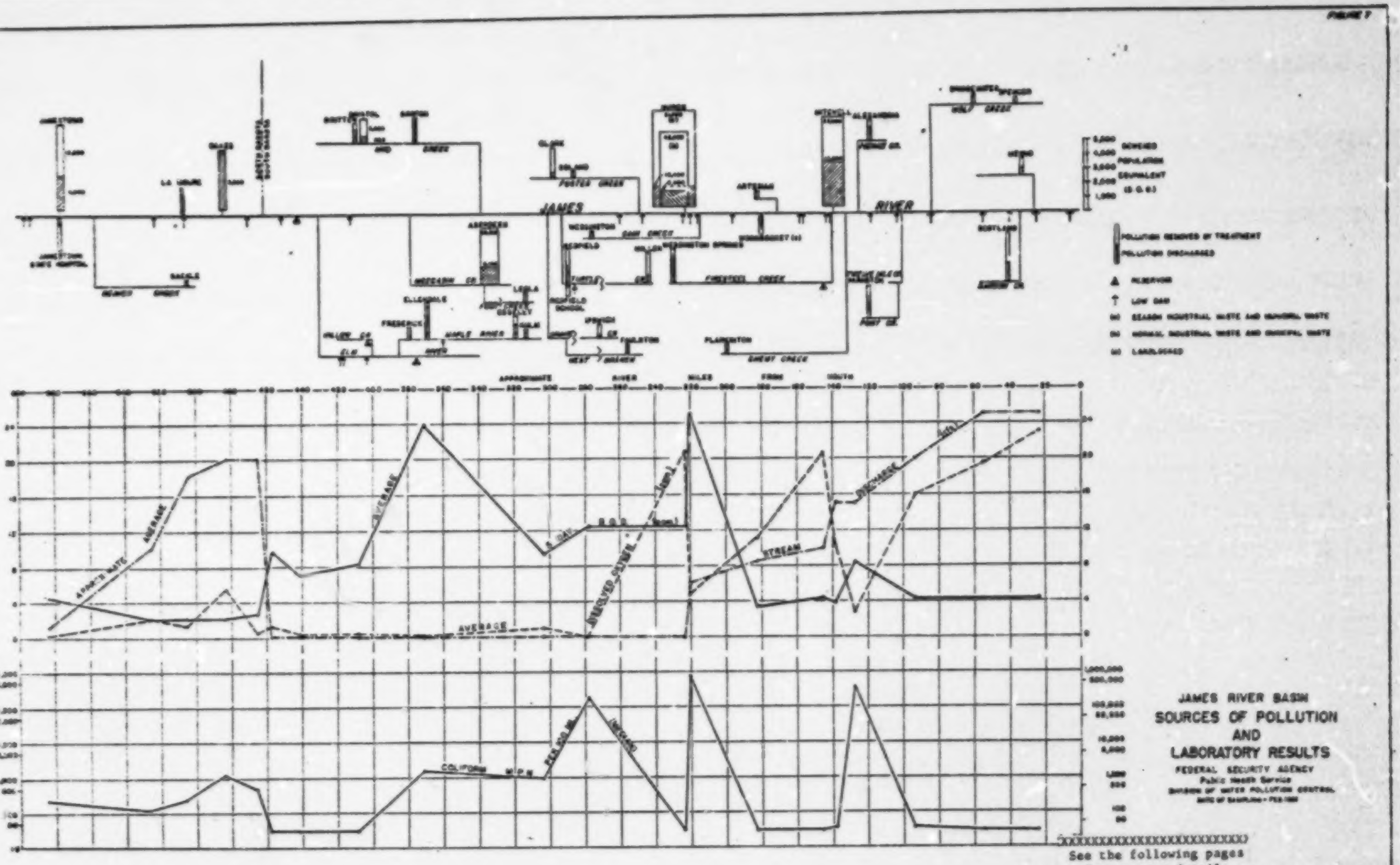
Probability of Low Flow Frequencies

Low flow periods are generally critical because of the reduced volume of stream water available for use. The probable frequency of these low flow periods gives an indication of how often critical conditions may occur and provides a firm basis for the design of waste treatment installed to relieve crucial pollution.

Critical oxygen depressions are more likely to take place during the summer time when high temperatures increase biological activity and reduce saturation limits of oxygen in water. Although cold weather conditions depress biological activity and increase oxygen saturation levels, the low stream velocity of the James is conducive to ice cover which prevents reaeration and causes oxygen depressions with concurrent nuisance conditions arising from decomposition of pollutional organic matter.

Low flows in the James River may be expected to occur at frequent intervals. Probable frequencies of low flows during the summer, fall and winter seasons are shown in tables 16, 17 and 18. It is of interest to note that minimum flows are, or approach, zero. Although these data have been greatly influenced by drought year records, the James River may be considered a stream deficient in firm, sustained stream discharges.

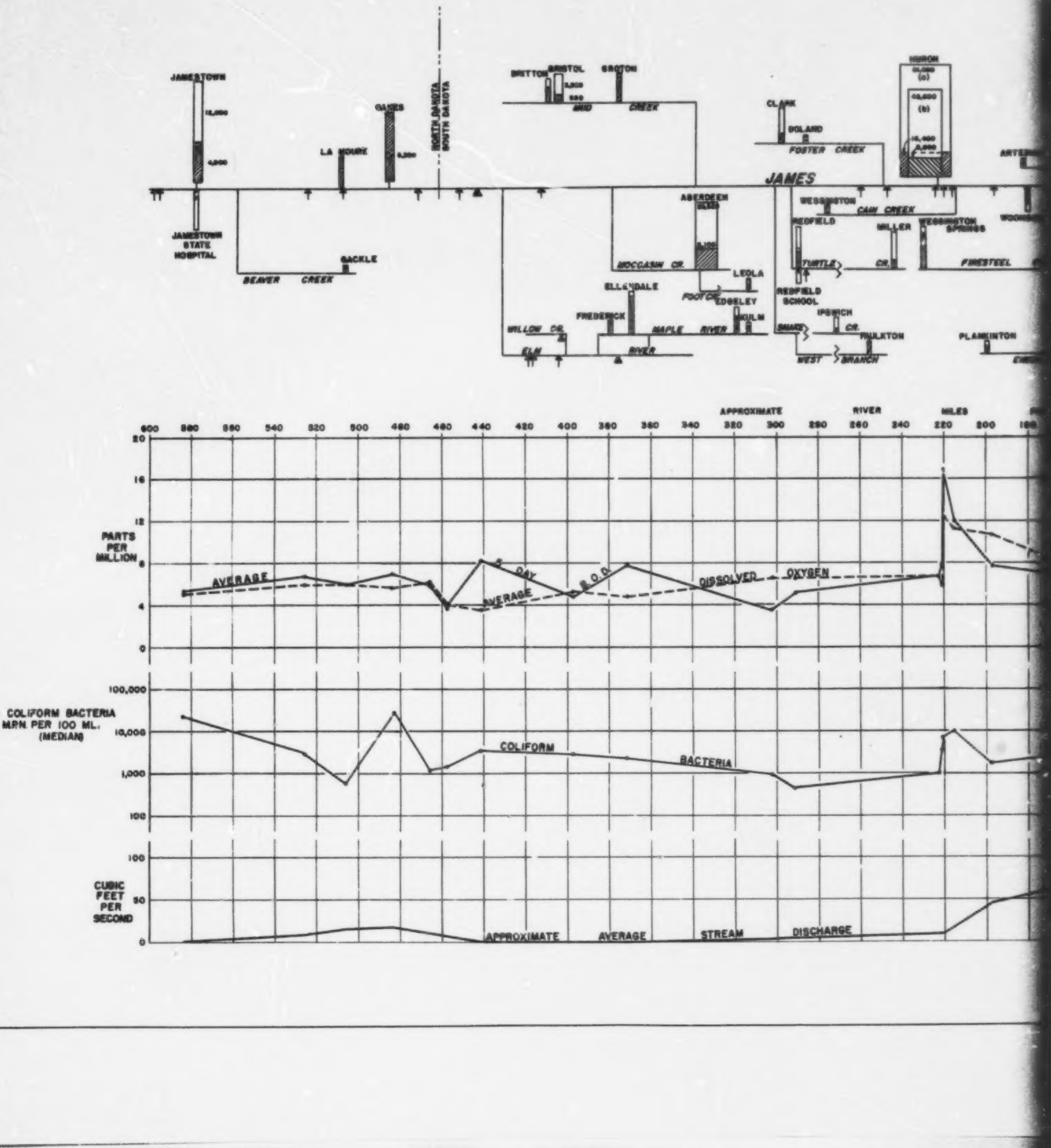
FIGURE 7



JAMES RIVER BASIN
SOURCES OF POLLUTION
AND
LABORATORY RESULTS
FEDERAL SECURITY AGENCY
Public Health Service
Division of Water Pollution Control

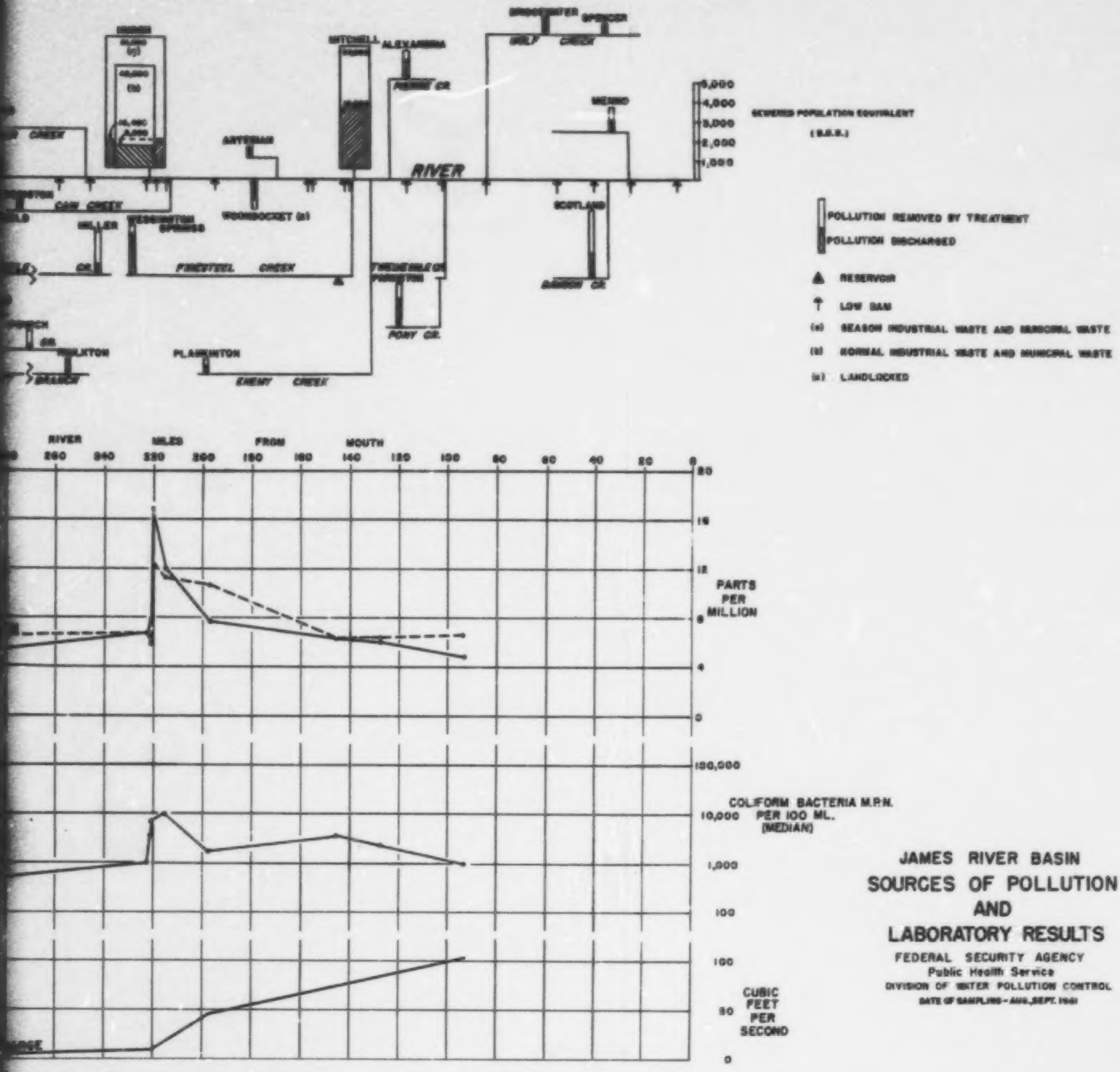
XXXXXXXXXXXXXXXXXXXXXXXXXXX
See the following pages
for greater detail.
XXXXXXXXXXXXXXXXXXXXXXXXXXX

37-a


JAMESTOWN
12,000
4,000
JAMESTOWN STATE HOSPITAL
LA MOURE
OAKES
4,200
NORTH DAKOTA
SOUTH DAKOTA
BEAVER CREEK
GACKLE
BRITTON
BRISTOL
3,300
500
GROTON
MUD CREEK
CLARK
DOLAND
FOSTER CREEK
HURON
(a)
(b)
16,400
JAMES
ABERDEEN
MOCCASIN CR.
LEOLA
FOOT CR.
EDGELEY
KULM
ELLENDALE
FREDERICK
WILLOW CR.
ELM
MAPLE RIVER
RIVER
WESSINGTON
CAIN CREEK
REDFIELD
TURTLE
MILLER
CR.
WESSINGTON SPRINGS
FIRESTEEL
REDFIELD SCHOOL
IPSWICH
SNAKE
CR.
FAULKTON
WEST BRANCH
PLANKINTON
ARTESIAN
WOONSOCKET
APPROXIMATE RIVER MILES
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
20
16
12
8
4
0
PARTS PER MILLION
AVERAGE 5 DAY B.O.D.
AVERAGE DISSOLVED OXYGEN
100,000
10,000
1,000
100
COLIFORM BACTERIA M.P.N. PER 100 ML. (MEDIAN)
COLIFORM BACTERIA
100
50
0
CUBIC FEET PER SECOND
APPROXIMATE AVERAGE STREAM DISCHARGE

B

FIGURE 9



JAMES RIVER BASIN

SOURCES OF POLLUTION

AND

LABORATORY RESULTS

FEDERAL SECURITY AGENCY

Public Health Service

DIVISION OF WATER POLLUTION CONTROL

DATE OF SAMPLING - AUG., SEPT. 1941

41-a

Table 16. James River Basin - Probable frequency of low mean monthly summer (Jun-Sep) discharge[1]

Years of record	Stream and location	Miles to mouth: James River	Miles to mouth: Tributary	Drainage area square miles	Minimum monthly mean flows in cubic feet per second that may be expected once in: 2 years	3 years	5 years	10 years	Minimum
18**	James River at Jamestown Damsite	582		-	3.0	1.8	1.4	1.2	0
18***	Jamestown Damsite	582		-	0	0	0	0	0
22**	Pipestem Creek	578		750	0.5	0.3	0.2	0.2	0
22*	James River below mouth Pipestem Creek	577		2,740	3.0	1.2	0.6	0.6	0
10	James River at Jamestown, N.D.	577		2,740	1.3	0.8	0.8	0.7	0.7
4	James River at Columbia, S.D.	440		7,050	0.4	0.3	0.1	0	0
4	Elm River at Westport, S.D.	429	20	1,680	2.5	1.5	0.8	0.3	0.3
4	James River at Ashton, S.D.	310		11,000	4.0	0.12	0.08	0.05	0.02
4	Turtle Creek at Redfield, S.D.	290	2	1,540	0.1	0.05	0.03	0.03	0.03
15	James River at Huron, S.D.	223		15,800	1.0	1.2	1.0	0.02	0
21	James River at Scotland, S.D.	33		21,550	1.6	0.7	0.7	0.3	0

[1] Based on U. S. Geological Survey data.

*Future flows below mouth.

**Past and/or future flows.

***Future flows below dam.

Table 17. James River Basin - Probable frequency of low mean monthly fall (Oct-Nov) discharges[1]

Years of record	Stream and location	Miles to mouth: James River	Miles to mouth: Tributary	Drainage area square miles	Minimum monthly mean flows in cubic feet per second that may be expected once in: 2 years	3 years	5 years	10 years	Minimum
22	James River at Jamestown Damsite	582			0.8	0.6	0.5	0.4	0.3
22	Jamestown Damsite	582			0	0	0	0	0
22	Pipestem Creek	578		750	0.6	0.3	0.3	0.3	0.2
22	James River below mouth Pipestem Cr.	577		2,740	0.7	0.4	0.3	0.3	0.2
10	James River at Jamestown, N.D.	577		2,740	1.2	0.9	0.8	0.7	0.6
4	James River at Columbia, S.D.	440		7,050	0	0	0	0	0
4	Elm River at Westport, S.D.	429	20	1,680	4.3	1.3	0.7	0.7	0.7
4	James River at Ashton, S.D.	310		11,000	1.8	1.4	1.3	1.3	1.3
4	Turtle Creek at Redfield, S.D.	290	2	1,540	0.2	0.1	0.1	0.1	0.1
15	James River at Huron, S.D.	223		15,800	6.7	2.2	1.1	0.5	0
21	James River at Scotland, S.D.	33		21,550	7.6	5.2	0.9	0	0

[1] Based on U. S. Geological Survey data.

Table 18. James River Basin - Probable frequency of low mean monthly winter (Dec-Feb) discharges[1]

Years of record	Stream and location	Miles to mouth: James River	Miles to mouth: Tributary	Drainage area square miles	Minimum monthly mean flows in cubic feet per second that may be expected once in: 2 years	3 years	5 years	10 years	Minimum
22**	James River at Jamestown Damsite	582			2.4	1.8	1.8	1.2	0.6
22***	Jamestown Damsite	582			0	0	0	0	0
22**	Pipestem Creek	578		750	0.4	0.3	0.3	0.2	0.1
22	James River below mouth Pipestem Creek	577		2,740	2.1	1.2	1.2	0.6	0.6
10	James River at Jamestown, N.D.	577		2,740	1.1	0.9	0.8	0.7	0.7
4	James River at Columbia, S.D.	440		7,050	0	0	0	0	-*
4	Elm River at Westport, S.D.	429	20	1,680	0.2	0.2	0.2	0	0
4	James River at Ashton, S.D.	310		11,000	0.1	0	0	0	0
4	Turtle Creek at Redfield, S.D.	290	2	1,540	0.3	0.3	0.2	0.2	0.2
12	James River at Huron, S.D.	223		15,800	3.1	1.9	1.1	0.6	0.5
19	James River at Scotland, S.D.	33		21,550	6.5	4.2	3.1	1.9	1.6

[1] Based on U. S. Geological Survey data.

*Indicates reverse flow due to backwater effect of Elm River.

**Past and/or future flows.

***Future flows below dam.

DISCUSSION

Municipal Water Supplies

Sixteen Basin municipalities in North Dakota and 61 in South Dakota use ground water sources. In addition, three institutions, North Dakota State Hospital at Jamestown, South Dakota State Hospital at Redfield, and the Training School at Plankinton, also utilize ground sources.

Water quality and quantity vary throughout the Basin. In South Dakota ground waters are generally high in total solids, sulfates, iron, manganese, fluorides, and hardness. Nitrates recorded in 1949 and 1950 did not exceed 1.0 ppm. for the 46 communities. Twenty-four of the 46 municipalities contained fluoride in excess of the normally accepted standard of 1.5 ppm.

In North Dakota considerable difficulty is experienced in getting ground water that is chemically satisfactory for human consumption. Failure of shallow wells has necessitated lowering to water-bearing strata and has generally resulted in a more highly mineralized water. High solids content, excessive hardness, iron, and manganese in objectionable amounts in ground water supplies are common. Chlorides and sulphates are present in concentrations above 250 ppm., a generally accepted standard. Edgeley, Ellendale, Forbes, and Fullerton have waters with excessive chlorides; Ellendale, Gackle, Kulm, and Verona have 250 ppm. or more sulphate in their waters. High nitrate values have been recorded for the well supplies of Forbes, Fullerton, and Medina. Edgeley's well water containes about 10 ppm. nitrates. Supplies at Ellendale, Forbes, and Fullerton contain fluorides in concentration greater than 1.5 ppm.

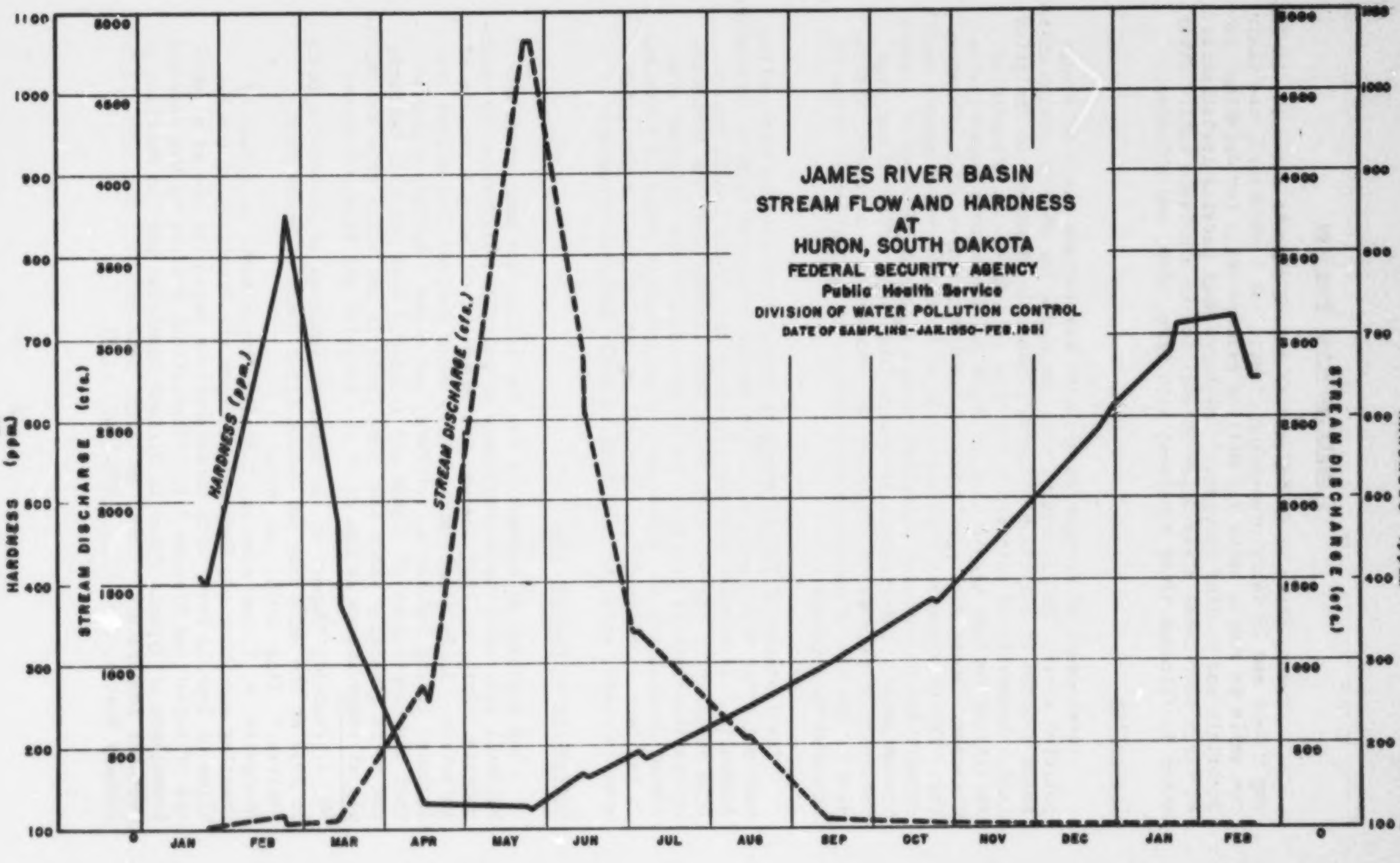
Aberdeen, Huron, and Mitchell, South Dakota, use surface water sources. Aberdeen, servicing about 21,000 consumers and several industries, uses 2.0-3.0 million gallons daily. Water obtained from Elm River watershed undergoes rapid sand filtration, softening, chlorination, and fluoridation. Softening reduces hardness (120 ppm. in April and 257 ppm. in January) to an average of 50 ppm. Taste and odor difficulties have been encountered. Allegedly, absence of an adequate water supply has limited industrial growth of Aberdeen.

Huron treats James River water in a new plant which began operation July, 1951. Filtration, softening, chlorination, and chlorine dioxide taste and odor control is practiced. The plant supplies 12,700 consumers with 1.0-2.5 million gallons daily. Present practice includes disposal of lime sludge to the James River.

Samples taken from the James River at Huron two days a month for the year 1950 and 1951 were analyzed by the City of Huron for hardness. A study of hardness and recorded flows for the days are shown in figure 10.

Mitchell constructed Lake Mitchell on Firesteel Creek for water supply storage. Treatment consists of filtration, softening, and chlorination. Turbidity problems have been alleviated by recently improved treatment facilities.

FIGURE 10



JAMES RIVER BASIN
STREAM FLOW AND HARDNESS
AT
HURON, SOUTH DAKOTA
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL
DATE OF SAMPLING—JAN. 1950—FEB. 1951

Industrial Water Supplies

Twenty-three of 90 industrial establishments surveyed, including 9 meat and 13 dairy processing plants, and 1 stockyard, use their own wells to supply about 1.1 million gallons daily for drinking, industrial, and cooling purposes. One large meat packing installation at Huron uses James River water in addition to a private well. River water is filtered after treatment with lime, alum, and chlorine.

Irrigation

Development of irrigation projects may include usage of sewage polluted water. Public health problems may arise when diversion units below sources of pollution disperse pathogenic organisms to irrigated land. Longevity of pathogenic bacteria is a factor in determining ability of various agents such as foods to disseminate communicable diseases. Among such agents may be fresh vegetables which are eaten raw. The ever-present possibility of such an occurrence causes health authorities to consider untreated sewage a potential means of disease transmission. Chlorination of sewage treatment effluents for high reduction of pathogenic organisms is recommended. A general discussion of the use of sewage-polluted waters for irrigation of crops is included in appendix C.

The instance of *Taenia saginata* infestation arising from eating beef which had been pastured on the sewage irrigated farm of Melbourne, Australia,[1] is further substantiation of the public health hazard. Data supplied by the Nebraska State Veterinarian show the incidence of cysticercosis in cattle to be 27 percent for the irrigated area around Scottsbluff and 7 percent for nonirrigated areas in Nebraska. It has been considered that shipment of cattle from the irrigated area increases parasite incidence in herds fattened elsewhere.

Harvesting of Natural Ice

The practice of harvesting ice for public use near Huron and Mitchell increases the significance of pollution discharged to watercourses. Prior to 1848 ice was not suspected of being a vehicle of infection. Leidy (1848) showed that water derived from melted ice included living infusoria, rotifers, and worms. Macfadyen proved that the temperature of liquid air (-315 F.) does not kill bacteria and it is generally known that some bacteria and molds grow and multiply at temperatures as low as 0° C. Sedgwick and Winslow[2] showed that under freezing conditions 50 percent of typhoid bacilli would be alive at the end of the first week, 10 percent at the end of the second week, and some may persist until 12 weeks. However, they considered that in nature the destruction of typhoid would be somewhat more rapid. S. C. Keith[1] states that low temperatures alone do not destroy bacteria but seem to favor longevity; at low temperatures metabolism ceases and the bacteria continue to exist in a state of suspended vitality similar to that exhibited by some plants in the far North.

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[1] W. J. Penfold: "Report on the Apparent Outbreak of Cystericus Bovis in 1933 at the Melbourne and Metropolitan Board of Works Farm, Weribee." (Aug. 1935) pub. date.

[2] Sedgwick, W. T. and Winslow, C-EA: (1) "Experiments on Effect of Freezing and Other Low Temperatures Upon the Viability of the Bacillus of Typhoid Fever with Considerations Regarding Ice as a Vehicle of Infectious Disease." (2) "Statistical Studies on the Seasonal Prevalence of Typhoid Fever in Various Countries and Its Relation to Seasonal Temperature." Mem. Am. Acad. Arts and Sc., Aug. 1902.12,5. Summary Boston, Soc. M.Sc. 1899-1900, 4:181.

Natural ice should be harvested from water of good sanitary quality and handled so as to prevent contamination. Natural ice should be used only for indirect cooling.

Epidemiologists have attributed the following disease outbreaks to ice: Typhoid fever, Plymouth, Pennsylvania, in 1885; intestinal disturbances at Rye Beach[2], New York, 1875; typhoid fever, St. Lawrence State Hospital[3], New York, 1903; and Elmira[4], New York, typhoid fever outbreak in 1923.

Water Quality

Hardness

Hardness is undesirable because it wastes soap and affects the skin unpleasantly, is less satisfactory than soft water for cooking and washing, produces scale in boilers, and is objectionable when present in some industrial processes. It has been found that softening of water presents many advantages. It reduces soap consumption and wastage, cost of replacing and maintaining plumbing, fuel losses due to scaling in boilers and water heaters, and increases wear and tear of fabrics.

A number of investigators have studied benefits due to water softening. Applebaum[5] writes that $44.00 would be saved annually per family of five by reduction in cost of soaps, plumbing bills, fuel losses, and decreased life of fabrics and cooking utensils. Hoover[6] reported savings of $48.42 annually for a family of five when a water with hardness of 70 ppm. was used in lieu of 270 ppm. He presented data to substantiate claims that the family could have afforded to pay five to six times existing rates, and that cost of softening was about one-eighth the costs of soap wastage. These figures do not include savings to industry. Estimates of softening costs vary from

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[1] Science, n.s. June 6, 1913, 37, 962: 877-879.

[2] Nichols, A.H. "Report on the Outbreak of Intestinal Disorder Attributable to the Contamination of Drinking Water by Means of Impure Ice." Seventh Ann. Rep. State Bd. Health, Mass., 1876, 467.

[3] Hutchins, R.N. and Wheeler, A.W. "An Epidemic of Typhoid Fever Due to Impure Ice." Am. J. M. Sc. 1903, 126:680.

[4] Am. J. Pub. Health 1924, 16:574.

[5] Water Works Engineering, Vol. 85, No. 15, July 27, 1932.

[6] National Lime Association, Bulletin 211.

75¢ to $2.00 per million grains of hardness removed in addition to fixed charges which may reach $2.50 per million gallons when softening features are incorporated in design of rapid sand filter plants.

The relation of hardness and stream discharge at Huron is presented in figure 10. Data from January 1950 to February 1951 show that hardness decreases as flow increases. During low flow conditions hardness attained a value of approximately 800 ppm. When discharge increased to about 5000 c.f.s. hardness was reduced to 130 ppm.

Huron has incorporated softening features in its new water treatment facilities. Reduction of raw water hardness by providing an increased steady flow would lessen loading, thereby providing benefits due to savings in chemicals used; the over-all effect would be lower cost of water for domestic and industrial consumers. Actual savings to water users is dependent upon imported water routing throughout the Basin and will require further study.

Modern dairies actually spend more time in cleaning up operations than in bottling or processing. Every piece of milk handling equipment is arranged so that it can be thoroughly cleaned. At the conclusion of processing, tanks are opened, pumps are taken apart, piping is disconnected, and all appurtenances are flushed out, scrubbed, and sterilized. Cleansing operations require large quantities of water, approximately 10 times the amount of milk handled. Quality of water used does not always meet most stringent standards such as the Drinking Water Standards (1946) of the Public Health Service as may be assumed by the consuming public. Scale is formed in boilers, hot water piping and heaters, pasteurizers, valves, bottle washers, and in bottles used for delivering milk. Results are waste of fuel, increased labor costs, repairs and replacements, and loss of pipe capacities. Moreover, scale in steam boilers causes hazardous overheating and failure of boiler metal and requires inactivation for chipping out procedures.

Forty-one of 90 industrial establishments surveyed were dairy products plants. It is reasonable to assume that benefits would be derived from provision of a more copious, improved quality water supply. The broad need for adequate supplies of soft water is indicated by the fact that in 1941, 35,000 industrial plants throughout the nation were softening water supplies.

Iron and Manganese

Iron and manganese influence water more from the standpoint of desirability than health. Surface waters contain some iron, and ground waters may bear it in excessive and objectionable quantities. Drinking Water Standards (1946) of the Public Health Service recommend that iron and manganese together should not exceed 0.3 ppm. More than this renders water unsuitable for domestic and industrial uses; it stains clothing during laundry operations, clogs pipes and discolors fixtures, interferes with industrial processes, and forms sludge in boilers. Industrial specifications are more stringent than the 0.3 ppm. for total iron and manganese content. Iron should not exceed 0.05 ppm. for some industries; iron causes spotting and discoloration of hides in tanning or processing of leather goods; and the distilling industry desires water free from iron and manganese. Table 37, appendix D, presents iron and manganese concentrations found in water supplies in the James Basin.

Total Solids

Total solids include dissolved and suspended material in water which is naturally derived from the strata through which water passes or the surface over which it flows. Suspended matter is harmful to industries using dyeing, bleaching, and scouring methods. In addition products may be highly discolored. Organic substances in water may seriously interfere with tanning, malting, and fermentation processes. Colloidal silica, although chemically inactive, may prove deleterious to boilers operated at high pressure. Dissolved sodium and potassium salts when present in boiler water may be responsible for "foaming." Sulphates are undesirable in boiler water but are advantageous in tanning and brewing processes.

The 1946 Standards of the Public Health Service state: "total solids should not exceed 500 ppm. for a water of good chemical quality. However, if such a water is not available, a total solids content of 1,000 ppm. may be permitted." Table 37, appendix D, includes among other analyses the solids content of water used by municipalities.

Taste and Odor

Taste and odor are important physical characteristics of a water supply because the public demands water that is good tasting and free from odors. Both qualities are closely related and often physical sensibility of taste is really odor. Odors are frequently present in surface supplies. Odors may be due to decomposition of organic matter, including natural flora and fauna present in surface sources.

Taste and odor problems have been experienced in waters utilized in the James Basin. Aberdeen, Huron, and Mitchell have developed in their water treatment plants special facilities to combat taste and odor.

Stream Conditions

The James River has a naturally high level of biological productivity. Discharged wastes augment naturally prevailing processes, and occasion some interference with normal biological life. Adverse effects of sewered wastes are generally local in extent. The impounded nature of the river encourages wastes localization, and its high inherent productivity, which assures actively functioning biological processes in all regions during most open water periods permits immediate attack upon various waste compounds.

Oxygen levels in the critical range - below 5.0 ppm -, with few exceptions, occur only under ice cover. If the incidence of winter kill among fishes may serve as a criterion, it may reasonably be assumed that critical oxygen conditions do not long endure over any significant length of stream in the region of larger impoundments.

Here the fish population is well developed and seems to have survived recent winters at least without excessive decimation. There can be little migration of fishes over dams during low water seasons, so the majority of them would appear able to endure local conditions of each reservoir. Depth of reservoirs appears insufficient to protect against deoxygenation, and, if maintenance of a fish population is an indication that low oxygen levels endure only over short lengths of stream or short periods of time, it may be reasoned that aeration by flow over dams or photosynthesis keeps levels above the lethal mark. Low stage discharges could hardly be expected to maintain oxygen content throughout each reservoir whereas photosynthesis could. However, the possibility that fishes are able to survive by crowding into upper ends of reservoirs should not be overlooked. Aggregations of carp were noted in a small open water area near Huron.

Chemical quality of James River water depends upon biological processes to a marked degree, and results of such activities are generally beneficial in reducing hardness and mineral content of water. However, biological growths periodically present complex problems of taste and odor in public water supplies.

Damage to Water Resources from Pollution

Discharge of insufficiently treated wastes to watercourses creates public health hazards and nuisances. The extent of damages that may be suffered are related directly to downstream water use. These uses may be briefly summarized as follows: (1) sources of supply for municipal purposes; (2) stabilization of sewage and industrial wastes after suitable treatment; (3) agricultural uses such as irrigation and stock watering; (4) water supply for manufacturing and industrial purposes; (5) natural ice; (6) propagation of aquatic and other wildlife; and (7) recreation.

Surface water shortages and poor quality of available ground water create undesirable situations in this area. Pollution affecting surface waters will become more and more significant as the need for water supplies increases. Pollution generally makes treatment more difficult and introduces possibilities of disease transmission.

There is a dearth of fishing and water recreation facilities in the major portion of the area, and therefore the real estate value of suitable locations is greatly enhanced. Angling is practiced wherever suitable conditions prevail. Discharge of excessive organic wastes will seriously depress or possibly deplete dissolved oxygen in sections of the stream, making the environment untenable for fish.

Nuisance conditions due to improper disposal of sewage occur near New Rockford, Jamestown, Oakes, and LaMoure, in North Dakota, and around Alexandria, Iroquois, Leola, Parkston, Dimock, Ethan and Redfield, South Dakota. Adequate treatment of wastes would result in many benefits to these communities.

The preceding discussion has dealt with the more tangible public health aspects and damages from water pollution. Other aspects such as psychological well-being, although admittedly difficult to evaluate, are worthy of consideration. Healthful recreation can do much to safeguard physical, mental, and moral health. The resultant values, could they be properly evaluated, would certainly be high. Thus, pollution contributed to streams in the James River Basin damages many of these intangible values in addition to tangible items previously enumerated.

Public Health Aspects of Polluted Irrigation Waters

Plans for water resource development in the Basin include extensive irrigation projects. Significant public health problems arise with use of sewage polluted waters for irrigation. Objectives for bacterial quality of irrigation water as recommended by the water pollution control agencies of North Dakota and South Dakota are presented in the section Pollution Prevention Measures Needed.

A review of literature on health hazards associated with irrigation reveals that use of polluted irrigation waters may transmit a number of diseases. An important consideration is the type of crop irrigated. Low-growing fruits and vegetables, such as celery, cabbage, carrots, and strawberries offer the most serious hazard. Of less significance are field crops, such as corn. Possible hazards to livestock, particularly dairy cattle, must receive consideration. Rural water supplies, sometimes taken from irrigation ditches, may be adversely affected.

Irrigation with sewage polluted water has the effect of removing polluted water from points of only limited access, such as streams, and distributing the pollution over a much larger area where it may come into contact with fruit, vegetables, grains, and livestock, depending upon local irrigation practices. The probability of transfer of infectious material from a diseased host to a healthy person or animal is considerably increased.

The sanitary survey—the locating of points of potential danger—is of great importance in any stream sanitation study. This report presents detailed information on the sources of pollution. Analyses of irrigation waters must be interpreted in the light of such survey findings. For example, the presence of coliform organisms in a headwater stream in the absence of known discharges of domestic sewage, even in large numbers, is less significant than when these same organisms are noted below a known sewer outfall. The time factor is also of importance in reducing bacterial contamination. A small amount of pollution near the point of irrigation water use may, from a health standpoint, have much more significance than a much higher pollution load discharged into the stream a considerable distance away. Storage in reservoirs increases time of flow, thus contributing to destruction of bacteria.

Sewage treatment processes remove large numbers of bacteria, but the usual municipal sewage treatment plant is not able to produce an effluent completely free from bacteria or other organisms pathogenic to man. Chlorination may be employed to reduce pathogenic organisms, however, such disinfection is not generally practiced at sewage treatment plants in the Basin. The same statement applies to the majority of sewage treatment plants in the United States. The approximate efficiency of various treatment processes as far as bacteria removal is concerned is shown in table 19.

Table 19. James River Basin - Bacterial efficiency of various sewage treatment processes[1]

Type of treatment	Percent removal of bacteria
Primary treatment	25 - 75
With chlorination	90 - 95
Chemical precipitation treatment	40 - 80
Secondary treatment	
Complete trickling filter plant	90 - 95
Activated sludge plant	90 - 98
Intermittent sand filtration plant	95 - 98
Any of the above with chlorination	98 - 99

[1] Modification from a table in Imhoff - Fair, Sewage Treatment, p. 6 (John Wiley & Sons, 1940).

Pollution Prevention Measures in Effect

Active programs have been maintained by the State water pollution control agencies of North Dakota and South Dakota for practical edification of treatment plant operators, and include short courses designed to improve the operation of existing plants. In addition, the agencies have familiarized the general public regarding the effects of pollution and thus have promoted many new treatment facilities and enlargements or additions to existing works. Cooperation between representatives of municipalities and industries is good, and has been reflected in practical agreements leading to use of municipal plants for treatment of industrial wastes. A respectful feeling of joint cooperation has existed as witnessed by existing contracts between industries and the municipalities of Huron and Mitchell, South Dakota.

Proper execution of the program requires provision for adequate budget and staff, and includes periodic investigation of communities, their wastes disposal facilities, and the effects of sewage and industrial wastes effluents.

Evidence of the early interest in wastes disposal is manifested by examples at Leola and Clark, South Dakota, where forerunners of present treatment works may be viewed. Composed of circular, Imhoff-like tanks, the plants were constructed shortly after the turn of the 20th century. At Clark this "old-timer" has been recently replaced by modern secondary facilities; Leola has yet to replace its facility. Achievement in wastes treatment is reflected in data presented in tables 20 and 21 which summarize existing municipal and industrial treatment facilities. Current status of municipal and industrial pollution abatement needs is presented in table 22.

Table 20. James River Basin - Existing municipal treatment facilities*

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary[a]	16	16	11,810
Secondary[b]	19	19	68,235
No treatment	13	-	9,305

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant centers or other population centers.

[a] Included are two septic tanks serving 3,300 people.

[b] Includes one municipality using lagoons to serve 700 people.

Table 21. James River Basin - Existing industrial treatment facilities*

Type industry	Number of plants	Number of industrial plants having:	
		Treatment facilities	No treatment facilities
Food and kindred products	13	6	7
Miscellaneous	1	0	1

*Industries having separate outlets discharging wastes directly to watercourse.

Table 22. James River Basin - Current status of municipal and industrial action on pollution abatement needs

Status of project	Number of municipalities*	Number of industries**
No action	26	10
Planning initiated	3	0
Final plans approved	0	1

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets discharging directly to watercourse.

Eleven municipal sources of pollution in North Dakota are listed in table 13. Carrington discharges the effluent of its secondary treatment plant to a dry run tributary to Kelly Creek. Jamestown and the State Hospital treat wastes by secondary facilities before disposal to the James River. Primary treatment is used by Edgeley, Gackle, and Kulm. Edgeley discharges into a dry run; Gackle uses the slough west of the town for disposal to an alkali lake; and Kulm sends its effluent to a slough. Septic tanks, not generally accredited with any consistent reduction of biochemical oxygen demand, are used by New Rockford and Ellendale. An efficiency of 10 percent has been assigned to the septic tank installation at Ellendale because of its adequate capacity and favorable operation. Sludge withdrawn from the New Rockford septic tank is pumped to the James River. Fessenden discharges its wastes to lagoons constructed in a slough. Untreated wastes are discharged to the James River by communities of LaMoure and Oakes. Industrial wastes are contributed to the main stem by railroad roundhouses at Jamestown. Dairy wastes at Jamestown State Hospital are dumped untreated to the James River.

In South Dakota 13 municipalities and 2 institutions have secondary treatment facilities. Eleven communities use primary treatment and 11 municipalities discharge untreated wastes to streams. Aberdeen is completing repairs to its secondary treatment plant. The new plant at Bristol needs improved operation. The Menno treatment plant is overloaded. Huron uses secondary treatment facilities which are overtaxed during peak industrial seasons. Mitchell, Redfield, and Scotland plants are overloaded, primarily because of industrial wastes. At Scotland, improved operation of the Imhoff tank would relieve the load placed upon the trickling filter unit and result in a better effluent. Clark and Ipswich have recently constructed new secondary treatment facilities. Miller recently overhauled its plant. Facilities at Wessington are inoperative. At Wessington Springs the trickling filter is not used and the works require general overhauling. Works at Plankinton Training School are adequate. Existing primary treatment facilities suffice for Carthage and Pierpont. The Emery plant requires improved operation. Alexandria, Britton, Iroquois, and Parkston have overloaded facilities. Willow Lake has recently completed a new primary treatment plant. Leola uses an outmoded, ineffective treatment unit.

Eleven communities in South Dakota discharge untreated wastes. Frederick disposes of its untreated effluent to Maple Creek, a tributary of Elm River. Dimock and Ethan do not have municipal sewerage systems, and dairy plants at these locations discharge wastes to ditches. Andover discharges its wastes to a dry run and creates nuisance conditions. Other communities contributing untreated wastes to watercourses include Artesian, Bridgewater, Doland, Faulkton, Groton, Highmore, Mt. Vernon, Woonsocket, and Wolsey.

Table 23 summarizes adequacy of existing works with particular reference to operation and capacity.

Table 23. James River Basin - Adequacy of existing treatment facilities - Municipal and industrial

Existing treatment facilities	Number	Adequacy with relation to: Capacity			
		Capacity		Operation	
		Satisf.	Unsatisf.	Satisf.	Unsatisf.
Municipal	35	21	14	22	13
Industrial	6	3	3	3	3

Trend of progress in pollution abatement is shown in table 24. In 1946 and in 1948 one municipal plant was completed; in 1950 and in 1951 three plants were constructed. While no progress is reported in industrial treatment works, the municipal treatment works constructed handle industrial wastes in the area.

Table 24. James River Basin - Progress in pollution abatement

	Municipal*		Industrial**	
Year	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	1	1,000	0	-
1947	0	-	0	-
1948	1	1,200	0	-
1949	0	-	0	-
1950	3	2,700	0	-
1951	3	2,645***	0	-

*Includes incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets discharging wastes directly to watercourse.

***Design population reflects only domestic wastes at Bristol, South Dakota. Industrial wastes not included in this estimate.

Review of State Water Pollution Control Laws[1]

In accordance with provisions of the "Memorandum of Understanding," appendix A, there follows a review of the water pollution control laws of North Dakota and South Dakota. Detailed information concerning criteria for State water pollution control and legislation is present in "Suggested State Water Pollution Control Act and Explanatory Statement."[2]

NORTH DAKOTA

I. General Statement

North Dakota has no comprehensive water pollution control legislation. The authority that exists is placed in the Water Conservation Commission, the State Department of Health, local boards of health under the supervision of the State Department, the Industrial Commission, and water conservation districts. Since no State agency has comprehensive authority in the water pollution control field, the Surgeon General has designated the State Department of Health as the State water pollution agency pursuant to the Federal Water Pollution Control Act.

North Dakota statutes relating to water pollution are found in R. C. 1943, 20-0124, 20-0612, 23-0109(4), 23-0307, 23-0405, 23-0407, 23-0502, 23-0512, 36-0705, 36-0714, 38-0804, 40-2204, c. 61-17, 61-0101, 61-0112, 61-0113, 61-0114, 61-0201, 61-0215, 61-0221, 61-0224, 61-0225, 61-0229, 61-0239; R. C. 1947 Supp., 21-0103, 23-0105, 23-0105(4), 23-0111, 40-0501(59), 40-2204, 61-0214, 61-0214f; and Laws 1937, c.255, Laws 1939, c. 256, Laws 1949, c.348.

II. Administrative Organization

1. Water Conservation Commission. The Commission, a public corporation, was established in 1937 (Laws 1937, c. 255) for water conservation, flood control, and the abatement of stream pollution. Its membership consists of the Governor, Commissioner of Agriculture and Labor, and five other members appointed by the Governor. The Commission may appoint assistants and fix their compensation. R. C. 1943, 61-0201 to 61-0213.

2. State Department of Health. The State Department of Health consists of the Health Council, the State Health Officer, the directors of divisions, and other employees of the Department.

The Health Council is composed of nine members appointed by the Governor. The members are representatives of various interested professions and groups and of the public.

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[1] Digests of State water pollution control laws prepared by Regional Attorneys, Federal Security Agency, Regions VII and IX, and the Office of General Counsel, Washington, D. C.

[2] Prepared by Division of Water Pollution Control, Public Health Service, Federal Security Agency, October 1950.

The executive officer of the Department is the State Health Officer who is appointed by the Governor. He must be a physician who has special training or experience in public health administration.

The Department has certain named divisions, including a Division of Sanitary Engineering. Other divisions may be added by the Council. The State Health Officer appoints and prescribes the duties of the division directors. R. C., 1947 Supp., c. 2301.

III. Powers and Duties

1. Development of Comprehensive Programs. There is no express statutory authority to develop a comprehensive program, to set standards of water purity, or to classify waters.

2. Issuance of Permits and Review of Plans and Specifications. No sewage disposal plant may be constructed without the prior approval of the Commission and of the Department of Health. R. C. 1943, 61-0221.

3. Enforcement. There is no express authority to hold hearings or to issue orders. Every person who willfully violates or refuses or omits to comply with any lawful order, direction, prohibition, or regulation of a board of Health or of a health officer is guilty of a misdemeanor and shall be punished by imprisonment for not more than 30 days or by a fine of not more than $1,000, or both. R. C., 1943, 23-0512.

Every person who throws or deposits any gas tar or refuse of any gas house or factory into any public water or into any sewer or stream emptying into public water is guilty of a misdemeanor, R. C., 1943, 61-0112.

The following acts are also misdemeanors punishable by a fine of not more than $100.

(1) The placing of dead animals, refuse, privies or privy vaults upon the banks or in the water of any lake or stream within the jurisdiction of the State:

(2) The placing of any structure or corral within which horses, cattle, swine, or sheep are kept within 60 feet of the top of the bank of a stream or lake;

(3) The placing of a slaughterhouse or grave within 80 feet of a lake or stream. R. C., 1943, 61-0113 and 61-0114.

Any person who places sawdust or other refuse in water in which fish abound, or in which the State or Federal Government has placed or may place fish or fish eggs is guilty of a misdemeanor and shall be punished by a fine of not more than $100 or by imprisonment of not more than 30 days, or both. R. C., 1943, 20-0124 and 20-0612.

To deposit liquid waste from a rendering plant upon the surface of the ground, or to dispose of it in a manner which makes any water supply unfit for human or livestock use is a misdemeanor punishable by a fine of not more than $100 or by imprisonment of not more than 90 days, or both. R. C. 1943. 36-0705 and 36-0714.

4. Conduct of Studies, Investigations, and Research. The Water Conservation Commission has power to investigate and plan all works, dams, and projects "to provide sufficient water flow for the abatement of stream pollution." R. C. 1947 Supp., 61-0214f.

The Commission may investigate, plan, and cooperate with other States, the Federal Government, and the Dominion of Canada for the purpose of preventing water pollution. R. C. 1943, 61-0224.

The duties of the State Health Officer include the duty to "study health problems and plan for their solution as may be necessary." R. C. 1947 Supp., 23-0105(4). The Director of the Division of Public Health laboratories of the Department shall, among other things "cause sanitary statistics to be collected and tabulated, and cause to be ascertained by research work such methods as will lead to the improvement of the sanitation of the various parts of the State;". R. C. 1943, 23-0109(4).

5. Cooperation with Other Public and Private Agencies. The Water Conservation Commission is authorized to investigate, plan, cooperate, and make all contracts or compacts with the United States, Canada, or any State for the purpose of preventing water pollution. The Commission may also accept and use any funds from the United States for such purposes. R. C. 1943, 61-0224.

Any State officer, department, or board which is authorized to deal with the United States or any State concerning water pollution must, before any action is taken, obtain the approval of the Commission. R. C. 1943, 61-0225.

For the purpose of obtaining financial aid from the United States, the Commission may adjust the plans and operation of any project to conform to the laws and regulations of the Federal Government. R. C. 1943, 61-0239.

The Department of Health is authorized to accept Federal funds for "public health work." R. C. 1947 Supp., 23-0111.

Municipalities are authorized "to accept aid from, cooperate and contract with, and to comply with and meet the requirements of any Federal or State agency for the establishment, construction, and maintenance of public works ... for the prevention of stream pollution or for sewage disposal ..." R. C. 1947 Supp., 40-0501(59).

6. Administrative Powers. The Statutes provide that all water within the State belong to the public. R. C. 1943, 61-0101. R. C. 1943, 61-0229, provides that the Water Conservation Commission "shall have full control over all unappropriated public waters of the State, whether above or under the ground, to the extent necessary to fulfill the purposes of this chapter." R. C. 1947 Supp., 61-0214, provides that the Commission "shall have full and complete power, authority, and general jurisdiction: ... "

"1. To investigate, plan, regulate, undertake, construct, establish, maintain, control, and supervise all works, dams, and projects, public and private, which in its judgment may be necessary or advisable:

. . . .

f. To provide sufficient water flow for the abatement of stream pollution;

"2. To define, declare, and establish rules and regulations:

. . . .

c. For the complete supervision and control of acts tending to pollute watercourses, for the protection of the health and safety of all the people of the State;

"3. To exercise full power and control of the construction, operation, and maintenance of works and the collection of rates, charges, and revenues realized therefrom;

. . . .

"5. To exercise all express and implied rights, power and authority, that may be necessary, and to do, perform, and carry out all of the expressed purposes of this chapter and all of the purposes reasonably implied incidentally thereto or lawfully connected therewith."

The powers granted the Commission do not limit or deprive the Department of Health of its jurisdiction to prevent water pollution. The Commission may not declare water polluted without a finding to that effect by the Department. R. C. 1943, 61-0215.

Although, as indicated above, the statutes do not expressly authorize the Commission to hold hearings or to order persons to cease polluting water, such authority would seem to be reasonably implied from the foregoing statutory provisions.

Statutes enacted prior to 1895 authorized municipalities to empty untreated sewage into streams, R. C. 1943, 40-2204. See also R. C. 1943, 20-0612 (enacted in 1909) and 61-0114 (enacted prior to 1895), which recognize this authority. Although these statutes have never been expressly repealed, it may be that the later statutes which established the Commission and granted it water pollution control powers modified them by implication.

R. C. 1947, Supp., 23-0103, provides that the Health Council shall: "Establish standards, rules, and regulations which are found necessary for the maintenance of public health, including sanitation and disease control;

R. C. 1947 Supp., 23-0104 provides: "All rules and regulations promulgated by the health council under the powers granted by any provisions of this Act (title) shall be binding upon all county and municipal health officers, . . . and shall have the force and effect of law."

The State Health Officer is required to enforce all rules and regulations of the Council and to hold local boards of health responsible for the enforcement of State regulations, R. C. 1947 Supp., 23-0105.

The county superintendents of public health are required, under the supervisory control of the Department of Health, to investigate public water and ice supplies which are suspected of being infected and to cause them to be condemned when necessary, R. C. 1943, 23-0307.

The county boards of health are authorized, under the supervisory control of the Department of Health, to supervise public water supplies and sewerage systems outside the corporate limits of any city. R. C. 1943, 23-0502.

City health officers are required to enforce the rules and regulations of the State Department of Health and of the city boards of health, the health ordinances of the cities and the health laws of the State. R. C. 1943, 23-0405 and 23-0407.

Water conservation and flood control districts may be organized on the approval of the Water Conservation Commission. The Board of Commissioners of such a district is authorized to make rules and regulations to prevent the pollution of water within the district. Laws 1949, c. 348, sec. 8.

The Industrial Commission is authorized to make rules and regulations which require oil and gas wells to be drilled, cased and plugged in such a manner that pollution of fresh water supplies will be prevented. The regulations may also require that a report of the plugging be made to the State Geologist within 60 days after completion of a well. R. C. 1943, 38-0804.

IV. Exemptions from Operation of Act

The only exemption from the water pollution control statutes is found in R. C. 1943, 20-0612, 40-2204, and 61-0114, supra, which may authorize municipalities to empty untreated sewage into streams.

V. Preservation of Existing Rights and Remedies

Laws 1937, c. 255, which created the Water Conservation Commission and granted it water pollution control powers provided in section 20 that nothing contained in the act should "repeal, amend, or modify any existing Acts or statutes pertaining to the appropriation or use of water except as herein otherwise provided . . ." A similar provision was contained in the re-enactment of 1939. Laws of 1939, c. 256, section 20.

As indicated above, R. C. 1943, 61-0215, provides that nothing in the act deprives the Department of Health of its jurisdiction to prevent water pollution.

VI. Statement of Policy

R. C. 1943, 61-0201, provides that the general welfare and health of all the people require that the regulation and prevention of water pollution necessitates the exercise of the sovereign powers of the State and that such regulation and prevention are affected with a public purpose; that the Water Conservation Commission in the exercise of its powers and in the performance of its duties shall be considered to be performing a governmental function for the benefit, welfare, and prosperity of all the people of the State.

Laws of 1937, c. 255, and Laws of 1939, c. 256, stated in sections 33 and 34 respectively that the provisions of the acts were severable and that if any one was unconstitutional, void, or inoperative, the others should remain in full force and effect.

VII. Interstate Agencies

North Dakota participates in the following interstate agencies:

(1) The Missouri Basin Health Council, which includes the States within the area of the Missouri Drainage Basin Office. The other States are Nebraska, Montana, South Dakota, Wyoming, Minnesota, Colorado, Kansas, Iowa and Missouri.

(2) Tri-State Waters Commission. The Commission's duties and powers include the abatement of pollution of the Red River. Minnesota and South Dakota are the other participants. R. C. 1943, c. 61-17; S.D.C., 55.4901 to 55.4905; M.S.A., 114.09 to 114.11; approved by Congress April 2, 1938, 52 Stat. 150. Although the life of the Commission has never been officially terminated, it has not functioned for several years.

(3) Inter-State Sanitary Committee. This is an informal agreement between the North Dakota, South Dakota, and Minnesota Health Departments. The Committee has materially contributed to pollution abatement of the Red River.

SOUTH DAKOTA

I. General Statement

Subject to vested rights and except as otherwise provided all waters within the State belong to the public. Pollution of streams by those over whose lands they pass is forbidden. SDC, 61-0101.

In 1935 the South Dakota legislature created a committee on water pollution. The committee is charged with classifying waters and preventing pollution of "Class A" waters.

The Department of Health also has certain duties and powers pertaining to sewage disposal and the prevention of water pollution.

Since the committee has comprehensive powers to prevent water pollution, the Surgeon General has designated it as the State water pollution agency pursuant to the Federal Water Pollution Control Act.

II. Administrative Organization

1. The committee on water pollution consists of the State Health Officer, who is ex officio chairman, the State Engineer, and the Director of Game and Fish. The Director of the Division of Sanitary Engineering of the Department of Health is the secretary and executive officer of the committee. SDC, 61.0106. The technical work, unless otherwise provided, is placed under the direction of the Director of the Division. SDC, 61.0108.

2. The Department of Health consists of the Public Health Advisory Council, the State Health Officer, directors of divisions, and other employees necessary to operate the Department.

The Council consists of nine members appointed by the Governor. They receive $10. a day while actually engaged in the discharge of their duties.

The State Health Officer is appointed by the Governor with the approval of the Council. He is required to be a graduate of a recognized medical school and to have had special training in public health administration. He must be licensed to practice medicine in South Dakota. He is the administrative officer of the Department and acts as secretary to the Council. Divisions are established and personnel appointed by him.

Laws 1949, ch. 105.

III. Powers and Duties

1. Development of Comprehensive Programs. Neither the Department nor the committee has specific statutory authority to develop comprehensive programs.

The committee shall classify the public waters of the State into "Class A" waters and "Class B" waters. "Class A" waters are those in which pollution can be so controlled that they shall not be unwholesome and unfit for domestic use or unsafe as a source of public water supply or deleterious to plant or fish life, or shall not cause a public nuisance. "Class B" waters are those which are more important to the welfare of the people as carriers of wastes, provided such wastes are not detrimental to the public health.

In passing on permits to create new pollution (see 2, infra) of "Class A" waters, the water pollution committee shall prescribe the standards of water quality and purity of sewage and industrial or other wastes necessary to maintain the receiving waters as "Class A." SDC, 61.0109, as amended by Laws 1947, ch. 416.

2. Issuance of Permits and Review of Plans and Specifications. No one shall cause new pollution in the form of sewage, industrial wastes or otherwise, of "Class A" waters without applying for and receiving a permit from the water pollution committee. SDC, 61-0109, as amended Laws 1947, ch. 416.

3. Enforcement. If investigation, at the direction of the committee, by the Director of the Division of Sanitary Engineering reveals unlawful pollution, the committee shall make an order requiring the alleged polluter to show cause why he should not be required to cease such pollution. After a hearing on the order to show cause, the committee may, if the evidence so justifies, further order the polluter, within a specified time, to refrain from the acts which cause the pollution.

The committee is required to keep a complete record of the proceedings before it. Its orders may be enforced by or appealed to the circuit court of the county where the pollution occurs. The appeal is on the record and is to the court without a jury except in cases where the right to trial by jury is preserved by the Constitution or by a statute. SDC, 61.0110 to 61.0116 and ch. 33.42.

The Public Health Advisory Council has the power:

> "4. To make, alter, and enforce, after approval of the Attorney General, orders, directions, or regulations as may be necessary to preserve and protect the public health and to regulate by requiring the taking out of licenses or other appropriate means, control, and, in proper cases, prohibit and suppress any of the following matters:
>
> . . . .
>
> "(b) The disposal of sewage:
>
> . . . .
>
> "(e) The pollution of streams and other waters:
>
> . . . .
>
> "The failure to obey the process, subpoena, order, rule, regulation, judgment or other legal command of the Council, or the violation of any rule, regulation, order or legal command of the Council may be enforced by proper legal proceedings in a court of competent jurisdiction."

Laws 1949, ch. 105, sec. 5 and 8

The council is required to keep a correct record of its proceedings. Any action by it is appealable to the circuit court. Upon approval of an appeal bond in the sum of $500. the order appealed from shall be stayed pending final determination of the controversy. The statute seems to contemplate an appeal on the record. Laws 1949, ch. 105, sec. 7, SDC, 27.0114.

There is no specific statutory authority for emergency summary action by either the Department or the committee.

Any person who violates the rules and regulations of the Department of Health is guilty of a misdemeanor. SDC, 27.9934.

Any person who places a dead animal or refuse in any river, stream, or lake, or in such proximity to such water as to cause pollution, is guilty of a misdemeanor. SDC, 13.1506 and 61.9901.

Any person who willfully and unlawfully commits any action which grossly endangers the public health is guilty of a misdemeanor. SDC, 13.1501.

4. Conduct of Studies, Investigations, and Research. It is the duty of the committee on water pollution to instruct the Director of the Division of Sanitary Engineering of the Department of Health to carry on such investigations as may be necessary. The committee may also on its own initiative or upon a petition of a municipality or board of health, or of 100 electors, cause the Director of the Division to investigate pollution of "Class A" waters. SDC, 61-0108, 61.0110, and 61.0111.

The Public Health Advisory Council has the power to make or cause to be made such investigations as may be required in the interest of public health. Laws 1949, ch. 105, sec. 5.

5. Cooperation with Other Public and Private Agencies. The statutes are silent with respect to cooperation with other public and private agencies, or with the United States or other States, and with respect to authority to participate in the benefits of the Federal Water Pollution Control Act.

6. Laws 1949, ch. 105, sec. 8 authorizes the Advisory Council to make such rules and regulations as are necessary for the proper administration of that chapter.

IV. Exemptions from Operation of Act.

"Class B" waters are exempt from the authority of the committee on water pollution.

V. Preservation of Existing Rights and Remedies.

No specific statutory provisions.

VI. Statement of Policy.

None.

VII. Interstate Agencies.

South Dakota participates in the following interstate agencies:
(1) The Missouri Basin Health Council, which includes the States within the area of the Missouri Drainage Basin Office. The other

States are Iowa, Nebraska, Montana, North Dakota, Wyoming, Minnesota, Colorado, Kansas and Missouri.

(2) Tri-State Waters Commission. The Commission's duties and powers include the abatement of pollution of the Red River. Minnesota and North Dakota are the other participants. SDC, 55.4901 to 55.4905; R. C. (ND) 1943, c. 61-17; M.S.A., 114.09 to 114.11; approved by Congress April 2, 1938, 52 Stat. 150. Although the life of the Commission has never been officially terminated, it has not functioned for several years.

(3) Inter-State Sanitary Committee. This is an informal agreement between the North Dakota, South Dakota, and Minnesota Health Departments. The Committee has materially contributed to pollution abatement of the Red River.

(4) The Public Health Service and the health departments of South Dakota, Iowa, Missouri, Kansas and Nebraska have entered into a written agreement effective January 1, 1950, to make a survey of pollution of the Missouri River from Yankton, South Dakota, to the mouth.

Pollution Prevention Measures Needed

Present water uses and increased usability due to improved water quality together with protection of water rights and property values largely determine pollution prevention measures needed. The objective of water pollution control programs is to preserve water quality to best serve these interests. Treatment requirements, like other aspects of water resources development, are generally influenced by economic considerations. The intangible aspects of moral obligations, aesthetic values, and nuisance conditions exert a powerful and positive influence on the justification of waste treatment facilities.

Quality objectives have been fairly well developed for such water uses as domestic and industrial supply, recreation, bathing, and fish life. Objectives for other uses are less well defined.

Among the more important goals of a water pollution control program is protection of water quality in streams used as sources of public water supplies. Raw water quality is an important factor in design, operation, and maintenance of water treatment facilities. The factor of safety which can be incorporated in the best water treatment facility varies inversely with the concentration of bacteria and toxic elements in the source of supply. Therefore, public health and waterworks officials generally measure water quality in terms of its bacteriological, physical, and chemical characteristics. While definite standards of raw water quality generally have not been adopted, the Manual of Recommended Water-Sanitation Practice, Public Health Service Bulletin No. 296, 1946, recommends the following criteria: Underground waters not subject to any possible contamination and meeting, in all respects, the requirements of the Public Health Service Drinking Water Standards as shown by satisfactory, regular and frequent sanitary inspections and laboratory tests, require no treatment. Underground or surface waters which are subject to a low degree of contamination not averaging more than 50 M.P.N. per 100 ml. in any month and meeting the requirements of the Public Health Service Drinking Water Standards in all other respects should receive a minimum of simple chlorination or its equivalent. Waters which require filtration for turbidity and color removal, waters of high or variable chlorine demand, and waters polluted by sewage to such an extent as to be inadmissible in the prior groups but containing numbers of coliform bacteria averaging not more than 5,000 M.P.N. per 100 ml. in any one month and exceeding this number in not more than 20 percent of the samples examined in any one month should be provided complete rapid sand filtration treatment or its equivalent, together with continuous post-chlorination. Waters which meet the requirements of the previous statement with respect to limiting monthly average coliform numbers but showing numbers of coliform exceeding 5,000 M.P.N. per 100 ml. in more than 20 percent of the samples examined during any one month and not exceeding 20,000 per 100 ml. in more than 5 percent of the samples examined during any month should be provided auxiliary treatment in addition to complete filtration and postchlorination. Auxiliary treatment as used here is presedimentation or prechlorination or their equivalents, either separately or combined as may be necessary. Long time storage for periods of 30 days or more represents a permanent and reliable safeguard which in many cases would provide something more than an effective substitute for one or both of the two other methods indicated. Waters which do not meet the requirements cited are considered unsuitable for use as sources of water supply unless they can be brought into comformance with the requirements by means of prolonged preliminary storage or some other measure of equal permanence and reliability as heavy prechlorination and preliminary coagulation and sedimentation.

In addition to recommended bacterial requirements, waters for public supply should not contain toxic, taste producing, or otherwise harmful substances, or organisms not readily and completely removed by water treatment processes. Also, water should be free of excessive amounts of acid, microscopic organisms, and organic matter causing any interference with the normal operation and efficiency of water treatment processes. Whether or not upstream domestic and industrial waste is treated thus often determines the acceptability of a water for domestic or industrial supply.

Standards adopted by the Public Health Service for Drinking and Culinary Water Supplied by Common Carriers in Inter-State Commerce prescribe limiting maximum concentrations of certain chemical substances inimical to public health, including the following:

Substance	Maximum concentration in parts per million
Lead	0.10
Fluoride	1.50
Arsenic	0.05
Selenium	0.05
Hexavalent chromium	0.05

These standards have received official approval by the American Water Works Association and general acceptance by official health agencies and water works authorities, and are widely used as one of the guides for evaluating water quality in administering a water pollution control program.

Also of importance are those substances which cause problems of taste and odor. Of particular concern are phenols and related compounds, minute concentrations of which cause repugnant taste and odor in water supplies. Pollution control programs aim for the practical elimination of these substances from domestic water supplies.

Quality requirements for industrial waters vary widely, depending upon the need of the industry under consideration. Of general concern are organic and biological constituents, toxic substances, and properties of corrosion, encrustation, and slime formation of the available waters. Waste control measures materially contribute to improvement of these qualities.

It is generally agreed that a minimum of 5.0 parts per million of dissolved oxygen is necessary, in streams of the area affording a suitable fishery habitat, for support of balanced aquatic life. Because of limited dilution water available during critical periods, secondary treatment, or removal of not less than 75 percent of the B.O.D., is required for most sources of pollution. Where the quantity of waste is large, as in principal towns where industry is concentrated, a degree of B.O.D. removal substantially in excess of 75 percent may be required to maintain desirable oxygen levels. Removal of B.O.D. approaching 90 percent is possible with properly designed and well operated secondary treatment facilities.

For bacteriological quality of irrigation water, the State water pollution control agencies of North Dakota and South Dakota recommend: (1) Sewage used for irrigation of forage crops should be given treatment insuring a consistent reduction in coliform bacteria of not less than 90 percent; (2) sewage used for irrigation of human food crops should be given treatment insuring a consistent reduction (a) in suspended solids of not less than 75 percent, (b) in 5 day 20° C. B.O.D. of not less than 75 percent, and (c) in coliform bacteria of not less than 98 percent, unless discharged into a stream where the volume of dilution water, available during the low flow periods during which irrigation diversions may occur, is at least 10 times greater than the anticipated maximum daily volume of sewage, in which case a bacterial reduction of 90 percent may be acceptable. Provided, however, that where the time of passage from plant discharge to irrigation diversion is such as to permit the normal death rate of bacteria as evidenced by the die-away curve to provide equivalent bacterial reduction, the requirement of (1) and (2) above may be appropriately modified.

Contamination of bathing waters by sewage, especially that of recent origin, is objectionable. Water for recreational usage should be free from floating solids, sludge banks, odors, and discoloration. The State Health Departments of North Dakota and South Dakota recommend that: "For bathing or swimming water, monthly arithmetical average 'most probable number' of coliform organisms should not exceed 1,000 per 100 ml. during any month of the recreational season; nor exceed this number in more than 20 percent of the samples examined during any such month; nor exceed 2,400 per 100 ml. on any day. For nonbathing or nonswimming waters, the monthly arithmetical average 'most probable number' of coliform organisms should not exceed 5,000 per 100 ml. in any month of the recreational season, nor should exceed this number in more than 20 percent of the samples examined during any such month."

Other indices of quality, as fecal streptococci, are receiving increasing attention although sanitary surveys must continue to play the major role in pollution control programs as related to bathing waters.

The protection of water rights must also be considered in determining pollution prevention measures needed. Comprehensive State water pollution control measures will not interfere with water rights under the three prevailing American legal doctrines of water law - the common law doctrine, reasonable use doctrine, and prior appropriation doctrine. None of these legal systems gives a license to pollute waters. West of the 98th meridian the prior appropriation doctrine is usually accepted, although in many areas State water laws incorporate a portion of both the reasonable use and prior appropriation doctrines. Where the doctrine of appropriated water rights prevails, consumptive use of water is permitted but no license is thus given to return water to the stream in a defiled condition. The water laws of the States of North Dakota and South Dakota contain applicable portions of both doctrines.

Waste treatment measures are usually designed to meet needs of a community following an engineering evaluation of local sanitary problems. Municipal treatment plants are primarily of two general types, one of which removes settleable material from liquid waste under quiescent flow conditions and the other removes nonsettleable and dissolved polluting material by biological means. Within these categories numerous combinations or adaptions thereof can be used to meet variant characteristics of waste from a community and treatment requirements indicated by the receiving stream water use. Industrial waste treatment processes vary widely, often within the same general type of industry. Changes in manufacturing processes and in by-products recovery, salvage and improved housekeeping practices may often prove very effective measures for reducing and thus controlling industrial waste pollution.

Control of industrial waste pollution may present an entirely different problem from that incurred in controlling municipal wastes pollution, since industrial wastes may contain toxic or otherwise objectionable substances not amenable to either sedimentation or biological treatment. However, the objective of the control program remains the same--protection of waters by reduction of objectionable substances to tolerance levels compatible with water uses. The water pollution control programs in this area are based on these premises.

While sewage and waste treatment processes cannot be controlled precisely, they can be regulated between rather well established limits. The effective removal of solids from domestic wastes by sedimentation is termed primary treatment and is generally considered to remove from 25 to 40 percent B.O.D.* The reduction of Biochemical Oxygen Demand by biological methods is termed secondary treatment. A plant incorporating effective primary and secondary treatment is generally considered capable of removing from 75 to 85 percent of the organic polluting material and may be capable of effecting 90 percent removal. Greater reduction, sometimes referred to as tertiary treatment, can be obtained by repetitive passages of wastes through the treatment processes or by increasing the number of combinations of treatment processes. All of these sewage and industrial waste treatment methods are effective in removing only the organic materials that can be removed by sedimentation or those that can be stabilized by biological action. Inorganic waste such as most acids, alkalies, salts and the metallic ions must be controlled by recovery, neutralization, storage, evaporation or other specialized processes. An excellent example of an effective method of controlling inorganic industrial waste is the return to appropriate underground formations of waters high in salt content which were originally pumped with oil to the earth's surface.

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*Biochemical Oxygen Demand is the quantity of oxygen utilized by microorganisms under aerobic conditions while feeding on and stabilizing organic materials.

In general, the water pollution control agencies of North Dakota and South Dakota have endorsed the following program:

1. Toxic substances including metallic ions, phenolic compounds, oils, alkalies, and acids should be virtually eliminated from sewage effluents.

2. Removal of settleable and floating solids to prevent sludge banks, floating materials, and nuisance conditions should be required as the minimum acceptable treatment.

3. For industrial wastes similar in nature to municipal wastes, treatment requirements should be based on the same premise as those recommended for municipalities. For industrial wastes not comparable to municipal wastes, treatment should be provided as necessary to prevent deterioration of water quality for beneficial uses in the receiving stream.

4. Additional treatment over that specified in item 2 above should be provided as necessary to protect downstream water uses.

Future water pollution control programs in the area will be largely a matter of extending present work with emphasis on:

1. Enactment of comprehensive pollution control legislation where needed.

2. Provision of treatment plants where none exist, and improvement of existing inadequate plants.

3. Dissemination of information concerning effects of pollution on public health, fishing, and other water uses.

4. Improving maintenance and operation of existing waste treatment plants.

5. Providing surveillance of stream conditions to supplement sewage treatment plant inspections so that needs for additional or improved waste treatment can be foreseen well in advance of actual necessity, thus enabling planning and construction to be carried forward.

Surveys of most of the sources of pollution in this region have been made by the State water pollution control agencies and reports, containing findings of the investigations together with recommendations for correcting or improving conditions, have been provided municipal and industrial officials and other interested parties. These reports serve to indicate the corrective measures needed. The State water pollution control agencies have further cooperated with representatives of numerous industries and municipalities through conferences on specific problems of pollution, and have worked closely with engineers employed by municipalities and industries to study pollution problems. These activities were inaugurated in the past as part of a continuing program.

Where engineering studies have been made they substantiate treatment needs as indicated in this report.

The ultimate step in the control of stream pollution is construction and proper operation of sewage and waste treatment facilities. Such action requires knowledge of sources of pollution and amounts of wastes discharged. This report delineates the sources and amounts of wastes; pollution abatement needs are depicted in figure 11. Subsequently these facts must be brought to the attention of public officials, industry, and the public at large so that they may act intelligently upon their local pollution problems. A sound body of law should be available in the States to support activities of the pollution control agencies.

Adequate stream flow as related to the degree of waste treatment provided is vital to the proper assimilation of wastes discharged to watercourses. A detailed discussion of this matter is presented elsewhere in this report and recommendations made for desirable minimum flows at various specific locations. Water resource development programs should include public health considerations. Minimum stream flows required for public health and stream sanitation needs are recommended by this report and should be provided wherever feasible.

The States in this area have made considerable progress in pollution abatement and both have promoted installation of adequate treatment facilities. However, statutory backing with effective laws is a definite need. Another handicap has been the lack of a sufficient number of technical personnel on the staffs of the health departments. Present key personnel are experienced and capable but cannot handle, unaided, the work load throughout the Basin.

The North Dakota State Department of Health, although long active in pollution control and abatement, has need for adequate supporting law and sufficient funds to secure personnel commensurate with the problems encountered. The existing legislation in South Dakota, although subject to certain defects, has been used effectively in the past and much can be accomplished under the current legislative statutes.

SEWAGE TREATMENT NEEDS

It is in the public health interest of the States to sustain most favorable stream conditions and preclude occurrence of nuisances. Stream sanitation can be maintained by construction of treatment plants to decrease pollutional loads contributed to watercourses. The necessary type of sewage disposal depends upon location, hydrology, nature of waste effluents discharged to streams, and downstream water uses. Primary treatment for removal of objectionable floating substances and settleable solids is regarded by the State water pollution control agencies as a minimum requirement. Secondary treatment is prerequisite when normal minimum flows are insufficient for adequate dilution of primary treatment effluents. When adequate dilution flows are not available for satisfactory assimilation of secondary treatment plant discharges, a higher degree of wastes treatment is needed. Normal minimum flow, the low stream discharge occurring often enough to provide a firm basis for sewage treatment plant design may be taken as the low mean monthly flow expected once in 5 or 10 years depending upon downstream water uses. Chlorination may be required for protection of downstream water uses such as municipal and industrial water supplies, irrigation, and recreation.

Sewage treatment needs are presented in table 25 and figure 11. Recommendations are founded upon conditions observed, combined with analyses of available records, and do not reflect increases or decreases in minimum flow as a result of the development program. Considerations include existence of natural pollution (other than sewage and industrial wastes) and its oxyger demand in the stream. In rural areas, farm wastes (natural or artificial fertilization practices are important factors) carried in surface runoff may supplement the organic matter in streams. Various characteristics of the drainage basin and its uses are implicated; among these are location, size, shape, slope and surface conditions such as cover and perviousness of soil.

Table 25. James River Basin - Needs for municipal and industrial waste treatment plants

	Municipal*		Industrial**
Needs	Number	Population served by facilities	Number
New plant	15	20,605	11
Enlargement or additions to existing plant	12	34,900	0
Replace existing plant	2	1,315	0
No project required	19	32,530	3

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers or other population centers.

**Industries having separate outlets.

The Basin lies in one of the most important waterfowl migration lanes in the country. White-fronted and Canada geese, using existing refuges during spring and fall migrations, and several species of ducks utilizing marshy areas along the main stem throughout spring, summer, and fall months, add organic pollution.

The principal interest is in stream behavior at times of low flow when natural pollution due to surface wash is at a minimum. Estimates of sewage treatment requirements have been based upon average monthly low flow conditions that may occur once in 10 years.

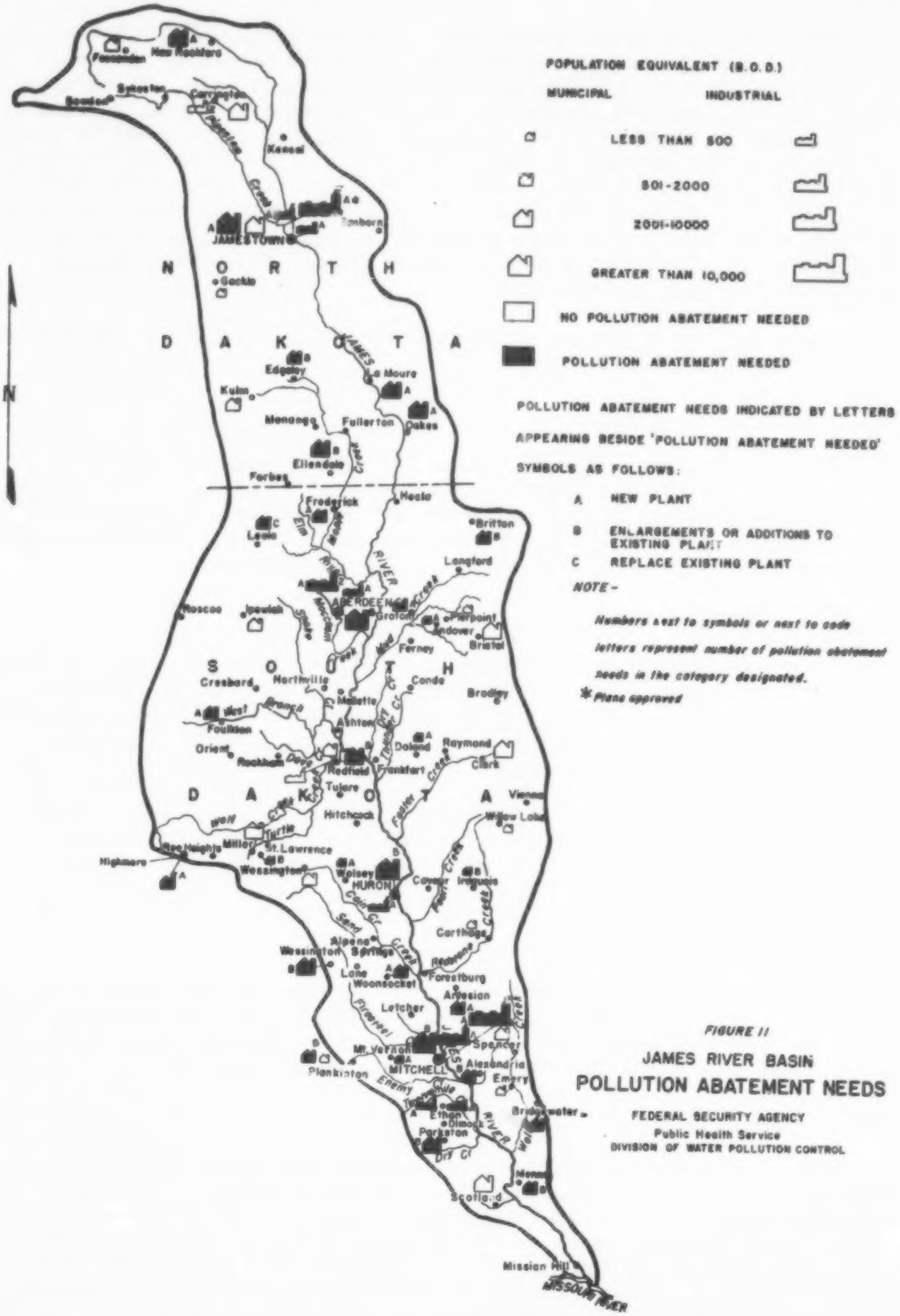
POPULATION EQUIVALENT (B.O.D.)
MUNICIPAL
INDUSTRIAL
LESS THAN 500
501-2000
2001-10000
GREATER THAN 10,000
NO POLLUTION ABATEMENT NEEDED
POLLUTION ABATEMENT NEEDED
POLLUTION ABATEMENT NEEDS INDICATED BY LETTERS APPEARING BESIDE 'POLLUTION ABATEMENT NEEDED' SYMBOLS AS FOLLOWS:
A NEW PLANT
B ENLARGEMENTS OR ADDITIONS TO EXISTING PLANT
C REPLACE EXISTING PLANT
NOTE -
Numbers next to symbols or next to code letters represent number of pollution abatement needs in the category designated.
* Plans approved
N
NORTH DAKOTA
SOUTH DAKOTA
New Rockford
Fessenden
Bowdon
Sykeston
Carrington
Kensal
Pipestem Creek
JAMESTOWN
Sanborn
Gackle
JAMES
Edgeley
La Moure
Kulm
Monango
Fullerton
Oakes
Ellendale
Forbes
Frederick
Hecla
Leola
Elm
Britton
RIVER
Langford
ABERDEEN
Roscoe
Ipswich
Groton
Andover
Pierpoint
Bristol
Ferney
Cresbard
Northville
Conde
Bradley
Mellette
Ashton
West
Faulkton
Orient
Rockham
Doland
Raymond
Redfield
Frankfort
Clark
Tulare
Vienna
Hitchcock
Willow Lake
Turtle Creek
Wolf
Ree Heights
Miller
St. Lawrence
Highmore
Wessington
Wolsey
HURON
Cavour
Iroquois
Sand Creek
Carthage
Alpena
Wessington Springs
Redstone
Lane
Woonsocket
Forestburg
Letcher
Artesian
Firesteel
Mt. Vernon
Spencer
MITCHELL
Alexandria
Plankinton
Emery
Enemy Creek
Ethan
Dimock
Bridgewater
Parkston
Dry Cr
Wolf Creek
Menno
Scotland
Mission Hill
MISSOURI RIVER

FIGURE 11

JAMES RIVER BASIN
POLLUTION ABATEMENT NEEDS

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

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Diversion of Missouri River water into the Basin would increase James River flow to such an extent that it may be necessary, in order to handle such flows, to eliminate existing low head dams. These alterations would bring about important changes in existing stream characteristics. Return flows from the developed irrigation units would be large. The Bureau of Reclamation estimated that flows of 1,000 to 3,000 second-feet would occur in dry years such as 1931-1942. It is probable that installation of regulation reservoirs would raise ground water levels in adjacent areas and convert some tributary streams from intermittancy to constant flow. The proviso that adequate minimal flows be sustained throughout the year is important.

There follows a summary of waste treatment needs for the individual communities of the Basin:

New Rockford, North Dakota

One of the larger communities in the upper headwaters region of the main stem, where the James is an intermittent stream, is New Rockford which discharges septic tank effluent and sludge. The North Dakota State Department of Health has recommended a new plant including secondary treatment to preclude occurrence of local nuisance.

Jamestown, North Dakota

Growth of Jamestown has overtaxed the existing plant, built in 1929. Expected low flow frequencies may change with completion of Jamestown Reservoir; however, a higher degree of secondary treatment is recommended pending ability of the water resource development program to provide materially increased flows, at which time primary treatment may be adequate. The Orleans Canning Company in Jamestown has plans already approved to replace lagoons with secondary treatment facilities. Jamestown State Hospital utilizes secondary works to reduce institution wastes. Stockyards and railroad maintenance shops require treatment facilities for reduction of industrial wastes.

LaMoure, North Dakota

This municipality discharges untreated wastes to the James below the CCC dam but into a pool created by the Dakota Lake Dam which backs water upstream for some distance. This practice damages water quality for all existing uses. Secondary treatment is recommended.

Oakes, North Dakota

At Oakes, domestic and industrial wastes are sent without treatment directly to the backwaters of Dakota Lake Reservoir. Reservoir releases constitute the James River flow across the North Dakota-South Dakota State boundary. Existence of a National Wildlife Refuge in the Dakota Lake area, recreational uses by citizens of nearby communities, and protection of the public health, make necessary secondary treatment of sewage. In this case pollution is an interstate problem.

Edgeley, North Dakota

Edgeley, with primary treatment, discharges into Elm River watershed from which Aberdeen, South Dakota, obtains its water supply. During dry periods it is exceedingly doubtful that flow from the sewage treatment works reaches Aberdeen. In times of heavy runoff, however, waste from this community may contaminate raw waters entering Aberdeen's water treatment plant. This pollution is interstate in nature. Secondary treatment is recommended to prevent the definite local nuisance which has developed.

Ellendale, North Dakota

Like Edgeley, Ellendale is geographically situated in the Elm River Sub-Basin; its wastes receive septic tank treatment before final disposal. Secondary treatment facilities are recommended to prevent interstate pollution.

Frederick, South Dakota

Frederick discharges untreated wastes to Maple Creek, tributary to Elm River above Aberdeen. Secondary treatment of sewage is recommended.

Leola, South Dakota

Leola possesses an obsolete treatment plant. During the field investigation it was noted that little change took place as influent became effluent. Secondary treatment is recommended. A similar plant constructed at Clark (circa 1913) has been replaced by an efficient secondary plant.

Britton, South Dakota

Primary effluent from Britton's treatment plant is discharged to an intermittent stream in which ponds form during dry weather. Overloading of existing treatment works indicates that a well operated secondary plant is needed to avoid local nuisance and insanitary conditions.

Highmore, South Dakota

Disposal is made to a dry run and results in local nuisances and odors. A secondary treatment works project should be initiated for this community.

Artesian, South Dakota

Artesian discharges untreated sewage to a small tributary. Secondary treatment of wastes should be accomplished in accordance with recommendations of the State Department of Health.

Bridgewater, South Dakota

Bridgewater discharges untreated wastes, and a secondary treatment plant is recommended. At present no action has been taken to provide treatment facilities.

Parkston, South Dakota

Parkston has a primary treatment plant. A dam upstream from the outfall sewer is used to flush sludge down Pony Creek, which is in very poor condition. Secondary treatment should be provided to alleviate pollution of this stream.

Plankinton, South Dakota

Plankinton has a primary treatment plant. However, nuisance conditions have been reported downstream. A secondary treatment plant as recommended by the State Department of Health should be installed.

Wolsey, South Dakota

Wolsey discharges untreated sewage. Secondary treatment should be provided in accordance with standards and specifications of the State Department of Health to reduce adverse effects of pollution in the receiving stream.

Woonsocket, South Dakota

Domestic and industrial sewage flows southward six miles into a landlocked lake. Nuisances sometimes occur and plans for the secondary treatment works should be activated.

Andover, South Dakota

The small community of Andover does not treat its wastes, which has caused deterioration of water quality in the receiving stream. A minimum of efficient primary treatment is recommended.

Groton, South Dakota

Groton's untreated sewage is discharged into a slough. Planning has been initiated for treatment of domestic and industrial wastes. Secondary treatment is recommended.

Faulkton, South Dakota

Faulkton is inactive in so far as treatment works planning is concerned. A new project is required at Faulkton to rectify local nuisances attending discharge of untreated sewage into the intermittent flowing watercourse The community is utilized by a large number of rural dwellers for buying, and for distribution of merchandise; the location of a hospital at Faulkton enhances its position as a center of population. The pollutional load contributed to Nixon Run often exceeds the actual resident population and secondary treatment is recommended.

Redfield, South Dakota

Redfield has a primary treatment plant and partial secondary facilities. A secondary plant is needed which can handle satisfactorily the combined municipal and industrial wastes of this community. The fact has been recognized and planning has been initiated.

Doland, South Dakota

Doland, a small municipality without treatment works, discharges to Foster Creek. Secondary treatment is needed to permit the stream to assimilate pollutional discharges.

Huron, South Dakota

Industrial wastes overload Huron's secondary facilities during late fall and winter periods when ice covers the James River. A higher degree of secondary treatment of adequate capacity is necessary to handle the seasonal loading.

Wessington, South Dakota

The sand filter plant at Wessington has been inoperative for some time. Condition of this installation is such that replacement of the original plant is necessary.

Iroquois, South Dakota

At Iroquois, enlargement of present primary works is recommended. The receiving stream, Pearl Creek, is in poor condition. Overall operation should be improved.

Wessington Springs, South Dakota

The plant at Wessington Springs should be structurally repaired and enlargement of present secondary treatment facilities is recommended.

Mitchell, South Dakota

Expansion of the community, including industrial development, has resulted in an overburdening of secondary treatment facilities at Mitchell. Mitchell requires a more adequate plant for the present loading; development possibilities point to inclusion of greatly increased plant capacity. Industries discharging to small tributaries should provide treatment for industrial waste before their release to streams.

Alexandria, South Dakota

Alexandria utilizes a primary treatment works. Discoloration of Pierre Creek, recipient of Alexandria's treated wastes, has been noted in addition to nuisances and odors. Secondary treatment is recommended.

Aberdeen, South Dakota

Wastes from industries located in west Aberdeen should be reduced by secondary treatment before discharge to the intermittent streams of the locality. Expansion of Aberdeen's industrial area due to the development of the Basin may be expected. Aberdeen recently improved the municipal treatment plant and the efficiency of this secondary plant should be re-evaluated.

Ethan, South Dakota

A small dairy product manufacturing plant discharges wastes to a ditch. The municipality of Ethan does not have a sewer system. Treatment for reduction of dairy wastes is recommended to relieve local nuisance conditions.

Dimock, South Dakota

Dimock has a cheese making establishment which lets its waste run into a railroad ditch near the factory. A small tank is used for minor treatment; however, some nuisance has resulted and more effective treatment is recommended. Dimock does not have community sewerage.

Mt. Vernon, South Dakota

This community discharges raw wastes to a small intermittent stream. Primary treatment should be installed to prevent local nuisances. Dry weather flow does not reach Firesteel Creek, but during periods of heavy precipitation discharge may reach downstream to Lake Mitchell, the source of Mitchell's water supply. Primary treatment is recommended as a minimum requirement by the State Department of Health.

Menno, South Dakota

Enlargement of present secondary treatment facilities is recommended.

STREAM FLOW REGULATION

Flow Needs: Benefits and Damages

The water resource development program planned for the James River Basin may increase minimum streams flows sufficiently to permit a lower degree of sewage treatment and to provide a more copious water supply of improved quality. These results would present tangible monetary benefits attributable to the program.

Specified desirable flows are those needed to assimilate residual organic matter contained in effluents of designated treatment processes without lowering the dissolved oxygen level in the stream below the minimum required for balanced aquatic life. Useful desirable flows (tables 26 and 27) are based upon existing treatment or a minimum of efficient primary treatment (35 percent B.O.D. removal) and 5.0 ppm. dissolved oxygen in the stream. Secondary treatment desirable flows assume efficient secondary treatment (75 percent B.O.D. removal) and 5.0 ppm. dissolved oxygen in the stream. Winter conditions and ice cover have been considered although no allowance has been made for stream flow losses occasioned by evaporation, ice formation and other factors.

Refinement beyond primary treatment represents a substantial financial investment. Possible benefits may accrue where flow can be increased to permit satisfactory stream conditions with primary treatment only, thereby effecting sizable savings in initial plant costs as well as operation, maintenance, and replacement. However, where secondary facilities are already in existence, benefit may accrue at some future time when replacement by primary facilities is permitted. Savings are considered as being directly due to stream discharge increments provided by the development program and benefits may amount to considerable sums when wastes effluents of many municipalities are discharged to a watercourse. Benefits have been assigned a monetary value based upon the differential of estimated annual costs of primary and secondary treatment (and in some cases a high degree of secondary treatment), amortized for 20 years at 4 percent interest plus maintenance and operation and reflect only present conditions.

Primary treatment is inadequate where the stream has a normal expected minimum flow less than the desirable flow, and a higher degree of treatment is indicated. In these instances primary treatment would be adequate if the regulation program made available a minimum flow equal to or greater than the desirable flow. Benefits would result in savings due to the lower degree of treatment required. No benefits for treatment are possible when normally expected stream discharges are equal to or greater than the desirable flow corresponding to primary treatment.

Damages may occur if flow regulation reduces stream discharges below: (1) the normal minimum flows, or (2) the flow required for ultimate disposal of primary treated sewage, whichever is lower. Damages represent the higher degree of sewage treatment necessary to maintain stream conditions equivalent to that prevailing before flow regulation.

If the development program provides desirable flows as recommended herein, benefits will accrue at Aberdeen, New Rockford, Jamestown, LaMoure, Oakes, Redfield, Huron and Mitchell (table 26). Jamestown has initiated plans for a new treatment plant. If flows of 80 c.f.s. for summer and 120 c.f.s. for winter can be provided by the development program, primary treatment will suffice. Benefits to the city, as given in table 26, are based upon provision of primary treatment desirable flows. If desirable flows are provided at Jamestown benefits would also accrue at LaMoure and Oakes. If desirable flows can be maintained in Moccasin Creek, benefits would accrue to Aberdeen. The development program may also realize tangible annual monetary benefits if desirable minimum flows provided by potential Turtle Creek Reservoir permit Redfield to reduce treatment facility replacement costs. Provision of adequate flows would benefit Huron and Mitchell. Improvement of Mitchell's highly overloaded treatment plant will be necessary irrespective of contemplated flow regulation in the James River.

Table 26. James River Basin - Flow needs and cost evaluation based on waste treatment

(1)	(2)		(3)		(4)		(5)		(6)
Municipality and State	Approximate miles from mouth		Minimum normal flow c.f.s.		Useful desirable[4] minimum flow c.f.s.		Secondary treatment desirable minimum flow		Annual tangible monetary benefits if flow in Col. 4 is provided
	Main Stem	Tributary	S[1]	W[2]	S	W[3]	S	W[3]	
New Rockford, N. D.	665		-	-	9	14	3	5	$ 3,400
Jamestown, N.D.	577		0.7	1.0	80	120	35	60	21,500**
LaMoure, N.D.	506		-	-	20	35	12	25	3,250
Oakes, N.D.	484		-	-	30	50	13	20	8,900
Aberdeen, S.D.	375	43	-	-	35	70	35	70	15,100***
Redfield, S.D.	290	2	-	-	(10*	15	4	6	5,000
					(4*	6	4	6	2,800
Huron, S.D.	223		-	-	65	200	65	200	59,000***
Mitchell, S.D.	137	2	-	-	55	140	55	140	35,000

*See following paragraph.

**New plant needed - present flows would require higher degree of secondary treatment. Primary treatment needed if specified flows in column 4 are provided.

***Based upon $10 per population equivalent for higher degree of secondary treatment required for winter conditions.

[1] Summer: June-September, inclusive.

[2] Winter: December-February, inclusive. [3] Based on ice cover.

[4] Based upon primary treatment or existing secondary treatment facilities. Primary treatment flows under estimated future conditions given in table 27.

Increased monetary benefits are attainable if a lesser degree of treatment is required due to the provision of adequate dilution waters under the Basin development program. In table 26 two benefits have been listed for Redfield. The $5,000 benefit is based upon a minimum requirement of primary treatment if sufficient dilution water can be furnished by potential Turtle Creek Reservoir. The $2,800 benefit represents possible savings in secondary treatment plant modification now under consideration and is contingent upon a lesser dilution flow volume.

Table 27 lists desirable primary and secondary treatment dilution flows for critical locations. Column 1 indicates the required flows necessary for dilution of existing treatment facility effluents. In the future replacement of present facilities will again pose considerations of treatment needs. Additional benefits would accrue if the development program provided desirable dilution flows for primary treatment effluents in lieu of secondary treatment desirable minimum flows specified in column 3.

Table 27. James River Basin - Flow needs in c.f.s. by months for critical locations

Month	Jamestown, North Dakota			Aberdeen[a], South Dakota			Huron, South Dakota			Mitchell, South Dakota		
	Existing	Future		Existing	Future		Existing	Future		Existing	Future	
	secondary treatment 75% removal B.O.D.	Primary treatment 45% removal B.O.D.	Secondary treatment 85% removal B.O.D.	secondary treatment 75% removal B.O.D.	Primary treatment 45% removal B.O.D.	Secondary treatment 85% removal B.O.D.	secondary treatment 75% removal B.O.D.	Primary treatment 45% removal B.O.D.	Secondary treatment 85% removal B.O.D.	secondary treatment 75% removal B.O.D.	Primary treatment 45% removal B.O.D.	Secondary treatment 85% removal B.O.D.
	1	2	3	1	2	3	1	2	3	1	2	3
January	60^{c}	210^{c}	70^{c}	70^{c}	295^{c}	90^{c}	200^{bc}	830^{bc}	230^{bc}	140^{c}	700^{c}	185^{c}
February	60^{c}	210^{c}	70^{c}	70^{c}	295^{c}	90^{c}	200^{bc}	830^{bc}	230^{bc}	140^{c}	700^{c}	185^{c}
March	60^{c}	210^{c}	70^{c}	70^{c}	295^{c}	90^{c}	200^{bc}	830^{bc}	230^{bc}	140^{c}	700^{c}	185^{c}
April	20	90	25	20	90	25	30	180	50	30	180	50
May	25	100	30	25	100	30	45	220	60	45	220	60
June	35	120	40	35	130	45	65	300	85	65	290	80
July	35	120	40	35	130	45	65	300	85	65	290	80
August	35	120	40	35	130	45	65	300	85	65	290	80
September	35	120	40	35	130	45	65	300	85	65	290	80
October	25	100	30	25	100	30	100^{b}	430^{b}	115^{b}	80	350	100
November	20	90	25	20	90	25	100^{b}	430^{b}	115^{b}	80	350	100
December	60^{c}	210^{c}	70^{c}	70^{c}	295^{c}	90^{c}	200^{bc}	830^{bc}	230^{bc}	140^{c}	700^{c}	185^{c}

[a] James River at Moccasin Creek.

[b] Seasonal industrial wastes add to pollution load.

[c] Ice cover.

1. Flows based upon present population equivalents and removal by existing secondary treatment facilities.
2. Flows based upon an increase of 100 percent population equivalents for the period 1950-2000 and improved primary treatment practices.
3. Flows based upon an increase of 100 percent population equivalents for the period 1950-2000 and improved secondary treatment practices.

There is uncertainty as to the effects of higher flow levels listed in table 27 during the winter months on flooding potentialities of the James River under present day channel conditions.

Flow Requirements for Future Population

Long range aspects of the development program have been considered in evaluating water uses over an extended period. Future flow needs for sanitation and water supply would be important. The Bureau of Reclamation has tentatively estimated population growths of the year 2000 (table 6 and fig. 2). Table 5 indicates projected growth of urban and rural population. Expansion of industrial activities has been discussed in the economic development section of this report.

Future population equivalents were assumed as being double those now existing. It has been assumed that improved primary treatment by the year 2000 would afford 45 percent removal of B.O.D. - improved secondary treatment, 85 percent. This latter assumption is considered conservative since comparable efficiencies have been attained at existing treatment plants through capable operation. Improved design and new methods may be experienced in the next 50 years to make these efficiencies common in the field of sewage treatment.

With materialization of the development program, it will be necessary to restudy municipal and industrial growth as influencing desirable flows. However, development of the Basin is founded upon importation of water from the Missouri River, and operation of the program should result in flows desirable for sanitation purposes.

Water Supply Benefits

The Bureau of Reclamation estimates that the water supply program of the James River Development Plan would make possible benefits of $437,000 to approximately 79,000 inhabitants of 39 municipalities (table 28), based upon anticipated net revenues of municipal water systems. Appendix B discusses some public health aspects of water supplies. The beneficiaries are reported to include Aberdeen, Alpena, Hitchcock, Huron, Miller, Mitchell, Redfield, and Wessington. Aberdeen will benefit if water is diverted into the Elm River Sub-Basin. Reportedly, industrial growth of the community has been retarded as a result of water shortages. It is probable that augmented stream flow would alleviate taste and odor difficulties.

Huron has experienced periods of inadequate water supply although available ground and surface sources have been used. The municipality recently completed construction of a six million gallons per day treatment plant which was placed in operation July 1951. Adequate water supply would enhance development of the Huron area.

Mitchell has used Firesteel Creek as a source of supply since the early 30's; during the drought period the reservoir was depleted to within 3,000 acre-feet of failure. Development of Firesteel regulating impoundment above existing Lake Mitchell would supplement present storage capacity and might improve chemical and bacteriological qualities of the lake water. Benefits may result from savings in chemicals

Table 28. **James River Basin - Municipalities which are expected to benefit from proposed development of municipal water supplies***

North Dakota

Bowdon
Carrington
Fessenden
Jamestown
Ludden
New Rockford
Oakes
Sykeston

South Dakota

Aberdeen
Alpena
Ashton
Athol
Britton
Columbia
Cresbard
Faulkton
Forestburg
Hecla

South Dakota (cont'd.)

Hitchcock
Houghton
Huron
Langford
Mansfield
Mellette
Menno
Miller
Mitchell
Northville
Orient
Redfield
Rockham
St. Lawrence
Scotland
Stratford
Tulare
Virgil
Warner
Wessington
Wolsey

*Data from Bureau of Reclamation.

required for water treatment and increased plant efficiency. In addition the community would be in a favorable position to expand industrially.

At Scotland, South Dakota, reports indicated surface supplies were unsuited for municipal use. During the summer of 1951 the lake at Scotland, used for recreational purposes, was closed to the public because of poor sanitary quality. Previous engineering studies sponsored by the community indicated that lake waters were inadequate, necessitating continued use of existing wells which provide a hard water high in total solids, sulphates, and iron. Continued industrial development at Scotland presents increased benefit possibilities from an improved water supply.

Dam and Reservoir Effect Upon Pollution Assimilation

Reservoirs effect attenuation of pollution by providing large volumes of dilution water. Further biological action and sedimentation of organic matter result from decreased water velocities. However, settling may cause localized nuisances by development of sludge banks which use available oxygen in surrounding waters. Clarification of impounded waters often permits increased development of algae which may cause taste and odor problems in downstream surface water supplies. Decomposition of excessive biological growths may pollute river reaches below the dam.

Faulkton and Cresbard are located above potential Cresbard Reservoir. Wessington Springs discharges treated wastes to Firesteel Creek. Sustained stream flow resulting from the development program may carry sewage waste from these communities into the potential reservoirs. Potential Firesteel Dam above existing Lake Mitchell would serve to provide additional storage for Mitchell's water supply.

Flow over spillways and tailrace structures contributes to the aeration of the water enabling a stream in some cases to assimilate greater pollutional loads. Numerous existing dams in the James aerate oxygen deficient waters when sufficient flow is available. Potential developments may require removal of those impoundment structures which tend to restrict the capacity of the stream channel and its ability to handle increased flows resulting from irrigation.

Effect of Reservoir Backwater

Construction of reservoirs requires consideration of possible backwater effects upon a waste disposal program. Backwater may inundate treatment facilities, or by enhancing sedimentation, create local nuisances. Firesteel Creek Regulating Reservoirs are now being considered in the Oahe Unit development plan and will be situated near Wessington Springs. The discharge of sewage treatment plant effluent into the reservoir may increase treatment requirements at Wessington Springs.

OBSERVATIONS AND ANALYTICAL RESULTS

Physical Features

Due to low stream velocity, the river shows no great tendency to shift its course, and has formed few marshy areas that are not restricted to thin belts along the stream margins. However, narrow marshes are numerous. The most extensive marsh development, abetted by construction of cross dikes and control structures, lies in the Sand Lake Migratory Waterfowl Refuge, a short distance below the North Dakota-South Dakota State line. The James receives marsh drainage from several tributaries, and at times must accommodate overflow from a few marshy lakes.

During dry seasons the river is essentially a series of separate impoundments or ponds. In some instances headwaters of one impoundment extend to the dam of the one just upstream, while in other localities stretches of unaltered stream occur between. The latter condition is more representative of the northerly South Dakota reach, where it appears normal for limited areas of the stream bed to become dry each year. Larger impoundments maintain water cover over the stream bed from the region of Station 9 to the mouth, although there is little discharge over dams above Huron during dry seasons. At Huron, discharges from the water purification plant - filter backwash and settling basins drainage - and sewage treatment plant maintain year-round flow. In early fall, 1951, entrance of ground water appeared to double this discharge by the time Forestburg was reached. There appeared to be appreciable accretion between Forestburg and Mitchell, and below Mitchell another increase occurred with discharge from the sewage treatment plant. At this season water in the impoundments moved downstream very slowly, noticeable currents being present only at reservoir inlets and for short distances below outfalls of sewage disposal plants. A fair current appeared to persist between pools in the stretch from below Lampe's Dam at Huron to just below Forestburg.

Ice breakup in 1951 showed influences of dams and channel constrictions. Ice cover was complete from the North Dakota-South Dakota line to the lower end of Sand Lake Refuge. From there the river was largely open down to the mouth of Moccasin Creek near Aberdeen, ice covered again to a point just below Ashton, open to the headwaters of the reservoir formed by the dam at Station 9, mostly covered with ice down to the vicinity of Huron, somewhat open from Huron to Forestburg, mostly ice covered from Forestburg to Mitchell, and completely open as far as examined below Mitchell.

Major river characteristics at each limnological sampling point are given in table 29. The majority of samples came from quiescent portions of impoundments. A dam at river mile 117 forms a pool that extends upstream approximately 22 miles to a point east of Mitchell. Other dams at river miles 139, 142, 155 and 157 furnish a series of adjoining impoundments extending above Station 23. Some alternation between reservoirs and unmodified reaches was possible above this point as indicated in table 29.

Bottoms normally contained considerable organic matter. Contributions of muck from marsh and other vegetation appear great, and are augmented in a few localities by sewage plant effluents. Oily material at Huron evidently originates from infrequent overflows of the railroad roundhouse collection pond, while oily tar below Mitchell was, until August 13, 1951, discharged as waste from the gas plant. Oil in bottom deposits at Tacoma Park was of undetermined origin. A deposit of lime sludge originating in the Huron water treatment plant covered the bottom for a few hundred feet at the bridge on U. S. Highway No. 14.

The usual low, vertical banks frequently give way to marshy margins. Banks are composed of mud and/or glacial till. Shores are infrequently wooded in the South Dakota reach above Huron. Margins of the long pool below Mitchell are generally heavily wooded, and scattered woods occur between Huron and Mitchell. The channel contains large quantities of fallen timber in many localities both above and below Huron.

Only Huron and Mitchell regularly discharge wastes into the South Dakota stretch, and only at these two municipalities is discharge of waste a constant influence upon the stream. Moccasin Creek, recipient of Aberdeen sewage treatment plant effluent, frequently has no flow for at least half of the year; and, when flowing, must meander about 43 miles from the point of sewage discharge before entering the James. Redfield discharges sewage effluent to Turtle Creek, which consists of a series of pools with little or no intervening flow in dry seasons. Flushing of these two streams adds to the organic load of the James.

Table [illegible]. James River Basin - Major features of each limnological sampling station

Station Number	Exact location	Approx. river miles above mouth	Mouth(s) of nearest tributary(ies)	Margins	Approx. discharge c.f.s. Spring	Approx. discharge c.f.s. Early fall	Type of habitat	Approximate depth low water stage	Bottom
1	Upper Sand Lake, S.D. Hwy. 10	448	Dry run 4 mi. upstream	Marsh and mud flats	0	0	Lake, narrow arm	7'	Deep muck, rocky margins
2	Lower Sand Lake	448		Marsh	0	0	Lake	6'	Deep muck, rocky margins
3	Just below Sand Lake	440		Marsh	0	0	Smooth stretch, isolated pool in summer	2'	Mud and muck
4	Below Lake, Columbia, S. D.	430	Elm River just below	Low steep mud banks	~50	0	Rapids, dry summer and fall	0	Rocks, sand, gravel, muck
5	Tacoma Park, S.D.	423		Mud banks	500	0	River impoundment, lake	6'	Silt with oily tar
6	N.E. Aberdeen, S.D.	380	Moccasin Cr. just above	Steep banks of glacial till			Rapids, dry summer and fall	0	Rocky, sandy muck pockets
7	Ashton, S.D.	305	Snake Cr. 3 mi. below	Marsh on left, mud bank on right	280	0.2	Smooth stretch	3'	Rocky, muck pockets
8	NE Redfield, S.D.	298	Turtle Cr. 1/2 mi. above	Mud and gravel banks			Pool in summer	2½'	Rocky, muck and sand pockets
9	Reservoir 1 mi. NE Lake Redfield	259		Gravel banks			Lake, river impoundment	7'	-
10	Just below dam of station 9	259	Lake Redfield outlet 1/2 mi. below	Gravel banks			Rapids, intermittent in summer	1/2'	Stones on bedrock
11	SE Lake Byron	242	Foster Cr. 2 mi. above Lake Byron outlet 1 mi. below	Marsh on left, mud bank on right	490	5	Headwaters river impoundment	4'	Gravel and rock, muck pockets
12	8 mi. NE Huron, S.D.	233	Shue Cr. 1 mi. below	Mud and gravel banks			Lake, river impoundment	3'	Gravel, sand and muck
13	4th St. bridge, Huron	225		Mud and gravel banks	490	0	Lake, river impoundment	3'	Rocky, muck pockets
14	Huron Water Works intake	223		Mud and gravel banks			Lake, river impoundment	7'	Rocky, sand and muck pockets
15	300 yds. below Huron city outfall	222		Rocky mud banks			Lake, river impoundment	4'	Rocky, muck pockets
16	Bridge just below Huron	221		Marsh on left, mud banks on right			Lake, river impoundment	6'	Muck with oily tar
17	1 mi. below station 16	220		Marsh on both sides			Lake, river impoundment	5'	Muck with oily tar
18	Just above Lampe Dam	219		Marsh on left, gravel bank on right			Lake, river impoundment	3'	Muck with oily tar
18A	Just below Lampe Dam	218.9		Mud banks on right, glacial till on left			Rapids	2'	Rocks, muck, and
19	5 mi. south of Huron	216	Outlet Stony Run L. 1 mi. above	Marsh on left, mud bank on right			Smooth stretch	1½'	Large stones, mud and muck pockets
20	13 mi. south of Huron	206	Pearl Cr. 7 mi. above	Mud banks			Rapids	1'	Sandy muck and sand bars
21	10 mi. N. Forestburg, S.D.	190	Rifle Lake Cr. 3 mi. below	Marsh and mud banks			Lake, river impoundment	3'	Muck and sand
22	2 mi. E. Forestburg, S.D.	180	Redstone Cr. just below	Banks gravel and sand	1,380	24	Rapids	1'	Sand and gravel, some muck
23	8 mi. N. Mitchell, S.D.	158		Mud banks			Lake, river impoundment	3'	Gravel, sand, and muck
24	6 mi. N. Mitchell	153		Mud banks			Lake, river impoundment	4'	Muck, some sand and gravel
25	3 mi. NE Mitchell	146	Morris Cr. 1 mi. above	Mud banks			Lake, river impoundment	4'	Muck, some sand and gravel
26	2 mi. E. Mitchell	142	Rock Cr. 1/2 mi. above	Mud banks, marsh just above			Lake, river impoundment	5'	Muck, some sand and gravel
27	200 yds. above Mitchell sewer outfall	139	Firesteel Cr. 1/4 mi. above	Mud banks tree covered	2,310	50	Lake, river impoundment	2½'	Sandy muck
28	1/4 mi. below Mitchell outfall	138.5		Mud banks tree covered			Lake, river impoundment	3'	Muck, covered with black gas tar
29	1 mi. below station 28	138		Mud banks tree covered			Lake, river impoundment	4'	Muck, covered with black gas tar
30	1 mi. below station 29	137		Mud banks tree covered			Lake, river impoundment	5'	Muck, covered with black gas tar
31	1 mi. below station 30	136		Mud banks tree covered			Lake, river impoundment	4'	Muck and sand, some tar
32	1 mi. below station 31	135		Mud banks tree covered			Lake, river impoundment	4'	Muck, sand, gravel
33	1 mi. below station 32	134		Mud banks tree covered			Lake, river impoundment	4'	Muck, sand, gravel
34	1 mi. below station 33	133		Mud banks tree covered			Lake, river impoundment	4'	Muck, sand, gravel
35	1 mi. below station 34	132		Mud banks tree covered			Lake, river impoundment	5'	Muck, sand, gravel
36	1/2 mi. below station 35	131.5	Enemy Cr. 2 mi. below	Rock ledges on right, and banks on left			Lake, river impoundment	5'	Rock ledges

Alkalinity

In winter of 1951 only total alkalinity was measured and averages are shown in figure 12 (91 samples at 20 stations). This curve substantiates the oxygen picture in indicating regions affected by photosynthesis. High alkalinities in the stretch from the North Dakota State line to just above Huron show that it was insignificantly influenced by the oxygen producing process, while much lower alkalinities at Huron and below indicated an intense rate of photosynthesis. High values in the middle region possibly reflected the alkaline nature of the soil in the old lake bed and/or some concentration by freezing. Maintenance of discharge helped keep alkalinity at a lower level in the North Dakota reach, where alkalinity of soil is apparently not as pronounced. Flow into the river below Huron undoubtedly combined with photosynthesis in reducing alkalinity.

In early spring alkalinity, occasioned by the presence of bicarbonate alone, was considerably reduced below winter levels by surface runoff (figure 8-A). Sections of the stream under ice cover were less diluted than those that were largely unfrozen. Lowest alkalinity occurred in regions with greatest discharge--stretches in both the upper and lower South Dakota reach.

In early fall alkalinity was due to the presence of both monocarbonate and bicarbonate ions. Photosynthesis generally maintained high monocarbonate alkalinity, giving peaks at Sand Lake, Huron, and below Mitchell where plankton organisms were most concentrated (figure 13). Bicarbonate alkalinity was reduced to the general level of 200 ppm. and suffered additional reduction in stretches where photosynthesis was most intense. Lowering of total alkalinity afforded by photosynthesis is apparently considerable in a stream of this type.

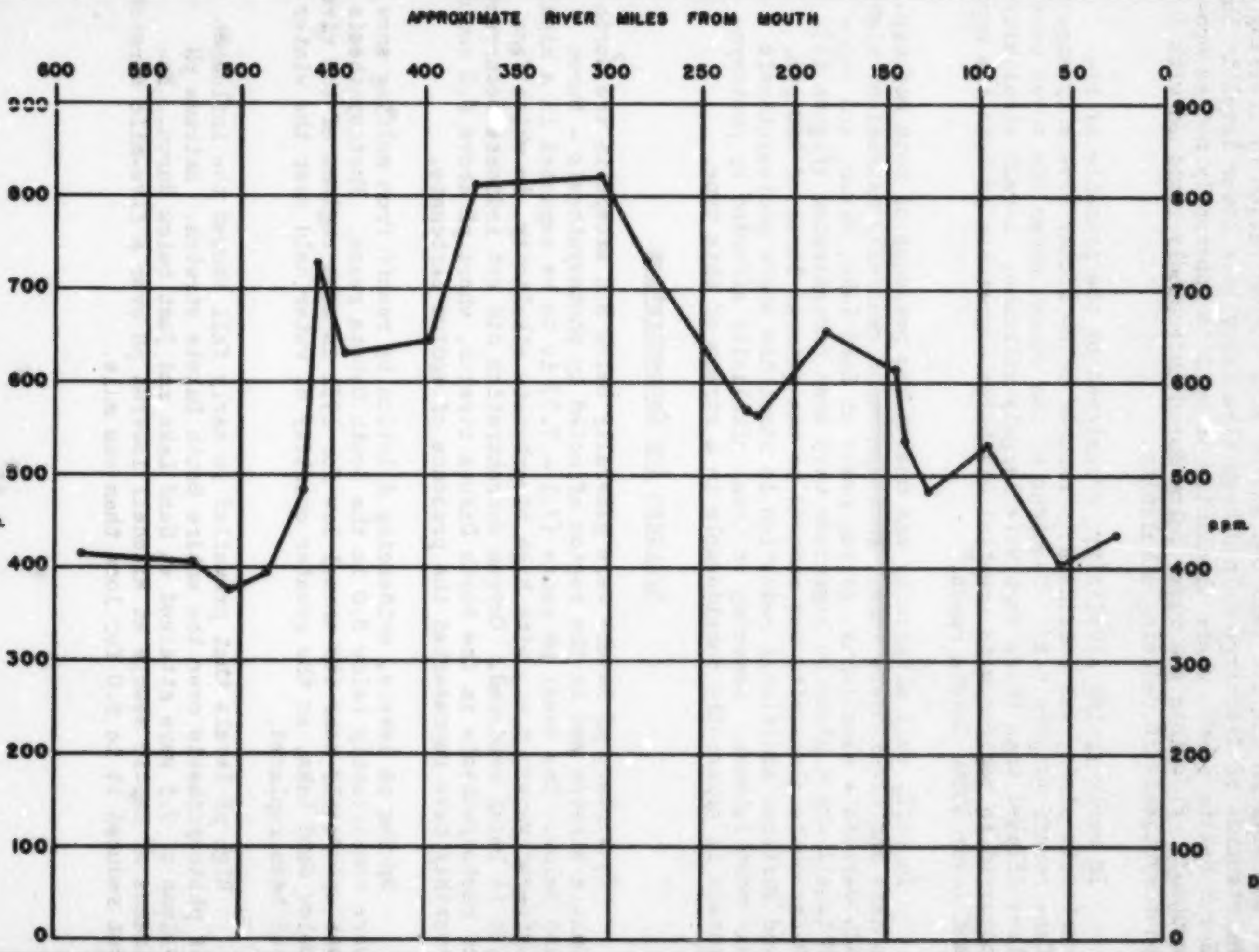
Hydrogen Ion Concentration

In winter, pH levels were generally below 8.0 except in the North Dakota stretch and in the region affected by photosynthesis - Huron and below. The usual pH range (7.1 - 7.7) is to be expected in a highly buffered water, i.e., with high bicarbonate alkalinity, in which free CO_2 is being produced. Oxygen concentration did not indicate occurrence of photosynthesis in the North Dakota stretch, where pH above 8.0 could possibly have represented the presence of sodium carbonate.

Spring pH levels, evidencing dilution by runoff from melting snow, were consistently below 8.0 in the South Dakota reach. Photosynthesis was apparently near its annual low for 1951 in most regions of the river below Sand Lake, as the greater quantity of water held over the winter had been replaced.

High pH levels that prevailed in early fall showed the influence of photosynthesis over the entire South Dakota stretch. Extreme pH values of 9.5 were attained at Sand Lake and just below Huron. Entrance of septic sewage at Mitchell lowered pH over a five-mile stretch, but reduced it to 8.0 for less than one mile.

FIGURE 12



JAMES RIVER BASIN

TOTAL ALKALINITY

FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL
DATE OF SAMPLING – FEB. 1951

Miscellaneous

Phosphate (PO_4)

In early spring, phosphate concentrations were rather high in the midsection of the river above Huron (1 ppm., figure 8-B) and for a short distance below Mitchell. It would appear that above Huron this salt was being added by runoff of snow melt which contained elements from fertilizer and manure. Its presence below Mitchell was evidently due to entrance of sewage effluent.

In late summer and early fall the Huron sewage treatment plant contributed considerable quantities of phosphate which were quickly used up by plankton. Lesser amounts contributed by Mitchell sewage met the same fate. Phosphate in Lower Sand Lake was believed to originate in the waterfowl population, as it also occurred in observable quantities in early spring. August, 1951, waterfowl population of this refuge was 21,360 ducks, plus 2 flocks of white pelicans, some cormorants, and large numbers of shorebirds. A daily maximum of 300,000 geese and 95,625 ducks used the refuge in early spring 1951. Spring chemical analyses of the lake were made on the day the greatest number of geese were observed by the refuge management. Above Mitchell some phosphate reached the river from cattle manure.

Nitrogen Cycle

Ammonia Nitrogen - A slight amount of ammonia also arose from waterfowl contamination in Lower Sand Lake, and cattle contributed measurable quantities a short distance above Mitchell in early fall 1951. However, with these two exceptions, ammonia could be traced directly to the entrance of sewage effluent. At Huron ammonia showed a progressive decline below the sewer outfall and disappeared within three miles. Records, while not covering a 24-hour period, appear to indicate that its concentration in the sewage effluent is relatively constant. Below Mitchell daily variation was indicated by peaks at rather uniform spacing in the first several miles below the outfall.

Nitrite Nitrogen - Nitrogen in this form apparently resulted only from sewage contamination. Its history at Huron in early fall was, in general, the same as ammonia, although its downstream decline was disrupted by an increase three miles below the outfall. Below Mitchell nitrite nitrogen was much less concentrated and varied inversely with ammonia, indicating that oxidation of ammonia was generally not accomplished until the river was reached. Nitrogen cycle analyses indicated noteworthy differences in quality of treated sewage discharged at Huron and at Mitchell.

Other Chemical Features

The U. S. Geological Survey, Water Resources Division - Quality of Water Branch, performed chemical analyses of water samples collected at Station 14 over the period November 11, 1950 to September 21, 1951. Results in ppm. of certain of these tests are given in the following table:

Table 30. James River Basin - Miscellaneous chemical analyses* - ppm. at Station 14 located at Huron, S. D.

Date	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Nitrate Nitrogen (NO_3-N)	Bicarbonate (HCO_3)	Sulfate (SO_4)
11/8/50	88	44	98	14	0.08	387	215
1/2/51	177	75	206	19	0.2	696	430
3/19/51	123	58	186	14	0.34	468	410
4/16/51	54	24	63	11	0.68	201	161
5/31/51	50	21	46	9.2	0.2	231	99
6/12/51	56	24	52	9.3	0.2	257	110
8/2/51	76	41	113	15	0.9	362	228
8/23/51	64	38	115	14	0.2	310	220
9/21/51	63	37	112	15	0.2	301	213

*Data from U. S. Geological Survey Records.

Analyses of the above and stream flow data indicate hardness and alkalinity reduction by dilution in the spring and by photosynthesis in late summer and early fall. The constancy of sodium and potassium concentrations during the latter period would appear to indicate that these cations were mainly present as sulfates. Inasmuch as Station 14 is above the source of pollution at Huron, the rather noteworthy nitrate nitrogen content indicates the stream's natural capacity for high biological productivity. Concentration of salts other than nitrates was greatest under ice cover in late winter. However, alkalinity at Station 14 (550 ppm.) where photosynthesis occurred, was considerably less than farther upstream (875 ppm.), where no effects of photosynthesis were evident.

In resumé it may be noted that chemical tests bear out the observation that natural contributions of organic matter considerably influence the James River. The annual variation in water chemistry is great and represents modifications by dilution with surface runoff, ice formation, and various biological processes, chiefly photosynthesis. Direct discharge of sewage effluent affected only minor distances of the stream, and in some instances influenced certain chemical factors indirectly by stimulating plankton growth. Huron sewage received effective treatment and apparently had no deleterious influences upon oxygen content of the stream during open water seasons. On the contrary, it would appear that its stimulation of photosynthetic organisms greatly improved the oxygen situation in the stream below. Sewage from Mitchell received unsatisfactory treatment during sampling periods, but since that effluent was discharged into relatively still water supporting a dense plankton population, its undesirable effects were quickly mitigated. Wastes from Aberdeen and Redfield had no observable effects upon water chemistry during either the spring or fall limnological surveys.

A noteworthy feature was oxygen supersaturation under ice cover at various locations along the stream below Huron. It must be suspected that such a condition is unusual for the James River and was permitted to develop by a very light snow covering. However, the fact that light penetration of the rather thick ice cover was sufficient to bring about this condition was unexpected.

BIOLOGICAL FEATURES

Bottom Organisms

During early spring it was not possible to obtain bottom samples at all stations, due mainly to a scattered ice cover that was unsafe to walk upon yet firm enough to resist breaking with a Petersen dredge. In some instances rocky bottom prevented dredging, and in those cases high water levels did not permit other collection procedures. In early fall, operating position of the regulatory structures at lower Sand Lake prevented dredging at Station 2, the river bed was dry at Stations 4, 6, and 7, the dredge could not be extended beyond the foot of the dam at Station 9, hand net collection was the one possible method at Station 10, low water at Station 21 covered only rocky bottom that could not be reached by wading, and marginal sampling alone was possible at Station 24.

Reference to bottom types listed in table 29 will show that organic sediments (muck) either formed the entire bottom or existed in large accumulations among other materials all along the South Dakota reach of the river. It would appear that most of the muck originates in natural sources, e.g., marsh, prairie, and woods vegetation, livestock, and waterfowl. Sewage discharges add to the mucky character of the bottom below Huron and Mitchell, but it has not been possible to determine the extent of bottom build-up due to waste solids from Aberdeen and Redfield. It may be assumed that organic sewage constituents from those two municipalities reach the James only intermittently. Since discharge of Turtle Creek has been noted to cause reverse flows in the river, it is possible that sewage solids from Redfield have been deposited both above and below its mouth. Snake Creek, a marshy stream, would appear to contribute organic matter to the region just above Turtle Creek. The situation at the mouth of Moccasin Creek, the carrier of Aberdeen sewage effluent, has been described in relation to B.O.D.

The majority of bottom organisms, whose concentration at various stations is shown in table 31, are characteristic of rich organic bottoms, and their value as indicator organisms in a river naturally providing such a desirable habitat as the James is limited. The almost constant appearance of two groups, the family Tubificidae (sludge worms) and the species Tendipes (Chironomus) militaris (a midge larva), in samples permits the assumption that they occur in some number in all regions of the river, and are absent only in limited areas, such as the first two miles below Mitchell sewer discharge, where tar deposit was toxic to all bottom organisms. Tubificidae spend all their existence in organic bottom deposits and their absence in the region of Station 29 indicated the general toxic nature of gas tar. The few chironomid larvae collected in that section came from extreme margins of the stream where tar deposits were slight or lacking. It would appear that their limited invasion of this section was facilitated by the aerial adult stage in their life history.

In early spring the chironomid larva T. militaris appeared in noteworthy concentrations at Stations 2, 7, and 19, while in early fall numbers were significant only at Stations 8 and 19. Tubificidae, in spring, were most numerous in samples taken at Stations 6, 9, and

Table 31. James River Basin - Distribution of bottom organisms, March-April 1951

Stations*	2	6	7	9	11	13	16	19	20	21	22	24
ANNELIDA												
Oligochaeta												
Tubifex	5	22	13	32	46	6	2		2			13
Limnodrilus				8	11			9	3	3		2
Hirudinea	3		6									
MOLLUSCA												
Lamellibranchiata												
Sphaerium sp.												2
Musculium sp.												2
INSECTA												
Ephemeroptera												
Hexagenia										3		
Caenis	10		3								3	
Trichoptera												
Hydropsyche									2			
Diptera												
Tendipes militaris	253	5	353	11	35	5	28	152	3	18	3	94
Tendipes [illegible]			6	165	184	67	14	22	19	101	48	118
Tendipes [illegible]	40	3	3									2
Tendipes [illegible]	13		2		10							
Tendipes [illegible]	3											
Tendipes [illegible]		2										
[illegible] sp.					3	3						
[illegible] [illegible]				2	5		2		34	312	30	73
[illegible] sp.					6				29	5	35	8
[illegible] culiciformis	21											
[illegible]	662											
TOTAL	1,010	32	386	218	302	81	46	183	92	442	119	314

*See table 29 for description of stations.

11, and, in fall, at Stations 8, 11, 19, 32, and 33. Station 7, at Ashton, may receive sewage solids originating in Redfield when Turtle Creek occasions reverse flow in the James, and this town may more regularly affect Station 8. Also, waste solids from Aberdeen may influence the river for a short distance below the mouth of Moccasin Creek; and particulate matter from the Huron and Mitchell sewage plants is definitely added to the river bottom. However, it is possible that organic sediments at Stations 6 and 7 were accumulated from natural sources, as they undoubtedly were at Stations 2 and 11. It appears that at Stations 8, 15, 16, 17, 18, 28, 29, 30 and 31 there was valid reason to believe that wastes significantly influenced the bottom.

On the debit side of the picture, oil and tar wastes below Huron and Mitchell definitely reduced bottom organisms in the first few miles below each municipality. Below Mitchell, bottom organisms were completely lacking at Stations 28 and 30, and at Station 29 were represented by a few chironomid larvae that were able to exist in a very restricted area on the extreme right margin of the river. The oily material at Huron restricted bottom organisms in the region above Lampe's Dam but did not completely eradicate them. No bottom organisms existed in the lime sludge banks discharged from the Huron water treatment plant.

Benthic animals vary in their tolerance of contributed pollution and usually only the most tolerant (so-called "pollutional" forms) exist in bottom deposits formed entirely by sewage solids. In such cases there is normally an increase in concentration of these species, but a reduction in number of different species present. Station 6 contained only pollutional forms in the spring, although in no great number, but was dry in early fall. If drying of this locality is an annual occurrence, bottom forms occurring there during the ice break-up season were in all likelihood displaced from farther upstream. At no other station were pollutional forms alone represented, and it appears unwise to place any special significance upon their presence at Station 6. At Station 5 only Tubificidae occurred in the dredge samples but May flies, snails, and amphipods were discovered among stones near the margins.

The greatest variety of benthic forms were present at Stations 1, 2, 7, 11, 19, 20, 21, 22 and 24, if both spring and fall samples are considered. The majority of species are to be expected in organic sediments accumulated from natural sources. Caddis fly larvae at Stations 20 and 22 were taken from riffles. Caddises also occurred under stones on Lampe's Dam. Bottom sampling in unaltered stretches in the upper South Dakota section did not include riffles due to difficulties previously described.

Dredge samples, results of which appear in table 32, do not offer a complete picture of bottom organism productivity in the James. At Station 1 (September) only a few *Hyalella knickerbockeri* were dredged, yet their concentration among small stones in shallow water amounted to several thousand per square foot. Snails, leeches, and damsel fly nymphs were also more numerous along the shore than in the area dredged. The same high marginal productivity was evident at Station 2. Shoreline areas also out-produced regions under deeper water at Stations 5, 11, 12, 19, 20, 22 and 29.

In brief resumé it may be stated that attribution of benthos stimulation to sewage solids appears inadequate to account for high concentrations in any region except possibly Station 8. At Station 19 the varied bottom fauna found in September was hardly characteristic of a sludge bank. It is not impossible that some sewage solids find their way to this locality over Lampe's Dam during high discharges, but at most they would appear to result in minor augmentation of organic matter arising from natural sources. The only direct effects on benthic organisms of waste discharge into the South Dakota stretch examined appeared to be suppression of benthos for short distances below Huron and Mitchell.

Mussels

The occurrence of living mussels is shown in table 32. The presence of fingernail clams, Sphaerium and Musculium, is to be expected in such an organic environment. Their empty shells were evident in all dredge samples, but living examples were found only in the region below Huron. Anodonta grandis was the single living species of Naiaidae encountered, and appeared in soft bottoms at Stations 1 and 19. Empty shells of naiads occurred at Station 22 (appendix D).

Attempts made to find live mussels on the shoal and bar at Station 22 met with no success, and since the majority of the shells were well buried in sand of the right bank, it would appear that the greater number of these species (appendix D) no longer exist in the James.

Fishes

Some of the larger reservoirs in the South Dakota stretch appear to support good fish populations (appendix D). Carp were widely distributed along the river below Huron and were concentrated in regions of the sewer outfalls at both Mitchell and Huron. In winter they were observed to concentrate in open water formed by discharge of cooling water from the large packing house at Huron. Black bass were observed only in the stretch between Stations 30 and 36, where they were frequently seen feeding upon small fishes concentrated near the surface. Walleyes were noted in the vicinity of Lampe's Dam just below Huron. Bullheads formed a major part of the catch of Sunday anglers, and were evidently abundant between Huron and Mitchell. Blue catfish were observed in the stretch between Station 13 and 36. Sticklebacks and bluntnose minnows were captured with a hand net in early spring below the dam at U. S. Highway 14 in Huron.

The upper South Dakota stretches also support a fish population. Carp and madtoms among others were present at Station 10. Fairly large numbers of small fishes were observed in Sand Lake, where a fair fish population appears necessary to support the pelican and cormorant observed at the refuge.

The value of the fishery supported by the James River may not be estimated from this investigation, but it does not appear to be fully exploited.

Table 32. James River Basin - Distribution of bottom organisms, September 1951. Numbers per square foot of bottom.

Stations **	1	2	5	8	10	11	12	13	14	16	17	18	16^x	19	20	22	23	24	26	27	28	29	30	31	32	33
ANNELIDA																					No organisms present		No organisms present			
Oligochaeta																										
Tubificidae	3		11	27		19	2	2	10	3	3	3		138	10	3			3	2				2	30	21
Hirudinea	6				P				2																	
MOLLUSCA																										
Gastropoda*	8	P	P															P								
Lamellibranchiata																										
Sphaerium														3		3	24								2	
Musculium														5		5	19									
Anodonta grandis	1													1												
Crustacea																										
Hyalella knickerbockeri	5	P	P		P																					
Orconectes sp.					P																					
INSECTA																										
Ephemeroptera																										
Hexagenia sp.				2										3	8		2		2	2				2		
Caenis sp.	13		P		P								P					P							2	
Odonata																										
Ischnura sp.	3	P			P																					
Trichoptera																										
Hydropsyche sp.													P			8										
Protoptila sp.															2											
Hemiptera																										
Corixidae				2																						
Diptera																										
Tendipes plumosus	5					2		3	5																	
Tendipes militaris				277		6	3		8	6	3	6	P	150	11	10	26		5	2		11		16	21	19
Tendipes decorus	42						3	3																		
Tendipes lobiferus					P																					
Tendipes [illegible]				2										2	16	3			2					2	2	
Tendipes senilis	2																									
Tendipes [illegible]																	2					2				
Tendipes flavus																5										
Tendipes sp.									8															2		
Cardiocladius obscurus																8										
Pentaneura carnea													P	1								2				
Metriocnemus sp. 1	8			2						2																
Metriocnemus sp. 2						35	3	2						5	2		6		3							
Palpomyia tibialis	5			2										11			3			2						
Hydrachnida	197																									

P - Organism present but number per area not computed.
16^x - On Lampes Dam - rock fill structure.
* - *Physa* sp.
** - See table 29 for description of stations. No samples collected at stations 3, 4, 6, 7, 9, 15, 21, 25, 34, 35, 36.

Plankton

Spring and fall plankton samples due to different methods of concentration are not strictly comparable. The relative concentrations of various groups at the different stations are shown in tables 33 and 34, and variation in total plankton densities along the river is given in figure 13.

In spring, plankton concentration was greatly influenced by surface runoff and lowest densities occurred in regions where most overwinter-water had been replaced. Entrance of new water was not uniform over the South Dakota stretch, and while old water was everywhere diluted, the damming action of long unbroken ice sheets still retained portions of old water in the stream.

A truer picture of plankton relationships was obtained in early fall when discharge was present only in the reach below Huron. Plankton densities were very high except in a shallow isolated pool just below Sand Lake and in the shallow stretch (Station 10) just below the dam at Station 9. The concentrations at those two points also (50,000 per ml.) would hardly be considered low. The general high plankton productivity is indicative of the high nutrient content of water over the entire part of the stream sampled.

Aphanizomenon was numerous at the two Sand Lake stations (1 and 2). Densities were, in all probability, greater than shown in figure 13 because some of the plants were lost by dissolution in the centrifuging process preparatory to making counts. In most regions of the stream Chlorococcales were dominant.

Responses of plankton organisms also indicated qualitative differences in sewage effluent at Huron and Mitchell. At Huron positive reaction to additional enrichment was evident as the effluent reached the river, while at Mitchell plankters were at first depressed and did not attain their maximum number until a few miles downstream. The lower density below Huron (Station 18-A) seemingly represented effects of Lampe's Dam. Maintenance of flow may have been partly responsible for the high level down to the region of Station 24, although there appeared to be additional response to enrichment at Station 19.

Qualitative aspects of spring plankton are shown in table 33. Species composition of fall samples is listed in appendix D Spring samples, concentrated with a plankton net which catches only those above 0.079 mm. in diameter, do not represent all forms then present. The indicated dominance of the green flagellate Euglenophyceae and diatoms Diatomaceae was in all likelihood quite correct. Plankton organisms showed no special relationships to pollution, since they were affected both qualitatively and quantitatively by nonuniform entrance of surface runoff.

Early fall responses to contamination were not characterized so much by the entrance of new groups below sewer outfalls as by the response of organisms already occupying a significant position in the plankton. The only organism that appeared to enter just below sources

Table 33. James River Basin - Distribution of plankton organisms. James River. March-April 1951. Numbers are per liter.

Station No.[1]	2	4	5	6	7	8	10A	11	13	14	16	19	20	21	22	25	27	36
MYXOPHYCEAE																		
Gomphosphaeria sp.								10	10									
Chroococcus sp.				1,160	180	20	210	150	650		10			10	10	70	20	30
Merismopedia elegans							10				10				10			
Aphanizomenon flos-aquae						10	40										10	
Oscillatoria sp.	10	10	40			150	20							10	10		10	30
Lyngbya sp.	10					410	90						10	10	10			
Nostoc sp.					10		10											
DIATOMACEAE																		
Cyclotella sp.												20						
Melosira sp.	10	20	20		10	50	30		10	250	60	70		50	20	190	180	220
Stephanodiscus sp.									10	10				10			20	
Gyrosigma sp.		40		20	50	110	20	30		20	10			10				10
Synedra spp.	30	90	70	230	120	310	100	20	40	350	220	160	10	180	130	180	40	70
Cymbella spp.	10		10			10												
Navicula spp.	140	60	190	200		380	130	180	60	390	260	160	20	780	990	570	700	550
Diatoma sp.		10	10		60	30			10									
Surirella sp.	10			40		30		10	10			10				10	10	10
Cymatopleura solea		10	10			10				10								
Cymatopleura elliptica																		
Rhoicosphenia curvata			20															
Nitzschia sp.		30	20	10		30		30	40	250	50	10			10	10		
Asterionella															10	10		10
Fragilaria spp.														10		10		
Pinnularia viridis																		
Hantzschia sp.																60	20	
CHRYSOPHYCEAE																		
Synura sp.									40	30								10
Stylobryon sp.									20									
Dinobryon sp.									50									
CHLOROPHYCEAE																		
Pediastrum duplex			10		10	40		10	10	10		10		10		10	10	40
Scenedesmus spp.		20	20		20	230	10	20	20	10	10			10	10	10	50	20
Scenedesmus bijuga					10	10												10
Ankistrodesmus sp.							10											
Spirogyra sp.	10	10	10											20				
Closterium sp.							10											
Hyalotheca sp.																		
EUGLENOPHYCEAE																		
Euglena spp.[2]	24,960	40	190	300	220	300	780	3,210	3,680	3,000	400	40	10	710	370	240	180	190
Petalomonas sp.										60		50	10		30	160	110	20
Phacus sp.									130	10	70							
Peranema sp.										10								
Trachelomonas sp.																	10	
DINOPHYCEAE																		
Peridinium sp.									1,710	20	100	70				10	10	40
PROTOZOA																		
Centropyxis aculeata						10		10										
Arcella sp.																		
Vorticella sp.	10					10		10										
Colpoda sp.							20			40					10	10		
Didinium sp.									20	10	20			10	10	10		20
Halteria sp.				60	10				40									
Chilodon sp.																		
Euplotes sp.	10		10	10					10									
NEMATODA																		
Nematoda spp.						10			10	10	10	10	10	10		10		
ROTIFERA																		
Polyarthra sp.	10	30	20	10		10	10	10	20	40						20	10	
Cephalodella sp.	10					10												
Triarthra sp.	10								20				10					
Brachionus spp.	10	10	40			30	10	20		30	20	20	20		20	10		10
Furcularia sp.																		20
Keratella									10			10						
Anarthra											20			20			20	20
COPEPODA																		
Cyclops sp.							20					10				10		
Juveniles	20							10	10		10		10					10
CLADOCERA																		
Bosmina sp.							10											
OSTRACODA																		
Ostracoda sp.			10							10								

[1] See table 29 for description of stations

[2] *E. acutissima*, *E. oxyuris*, *E. spirogyra*

Table 36. James River Basin - Distribution of plankton organisms, James River, September 1951. Numbers are per milliliter.

Station Nos.*	1	2	3	5	8	9	10	11	12	13	14	15	16	17	18	18a	18b	19
MYXOPHYCEAE																		
Oscillatoria	2						1,500	39	13	21	70	830	2,500		1,600	1,600	3,000	
Aphanizomenon	1,404	702	18	3	2,800	4,200	2,400	1,200	13,000	574	386	830	830	6,600	10,000	5,000	5,000	5,000
Anabaena						1	1	1				3						
Microcystis	1	1																
Merismopedia												830	63	4	3	5,000	1,600	
BACILLARIEAE																		
Melosira	21	198	[illegible]	87	12	27	39	13	160	670	456	10	26	32	1,600			787
Gyrosigma	1	28	70	4	37	25	34	1,053	42	17	36	16		33				31
Cyclotella				2,633								8,000	8,000	12,000	8,000	18,000	22,000	12,000
Synedra									8,300	1,600		14,000	25,000	43,000	27,000	12,000	22,000	5,000
Rhizosolenia					14	7	7	75,000	4,800						1,600		5,000	2,000
Surirella																		
Others	33	315	876		85	6	25								8			
CHRYSOPHYTA																		
Chromulina												1,600	1,600				1,600	
CHLOROPHYCEAE																		
Volvocales		1,600		3,000	1,600	6,600	1,600	3,200	1,600	10	6,600	29,000	25,000	35,000	27,000	23,000	33,000	6,600
Chlorococcales																		
Pediastrum	3	17	18	11	19	2			1			16						2
Scenedesmus	6	28	70	5	340	8	14	17	117	88	175	8,000	14,000	16,600	6,600	3,300	10,000	1,800
Closteriopsis		17	15	7	27		8	1	29	12	32							70
Actinastrum		34	54	1	1	2	2	5	5	22	22	1,600	3,000	18,000	1,600	1,600	1,600	50
Others	180,000	208,000	55,000	175,000	140,000	63,000	46,000	63,000	138,000	325,000	195,000	360,000	492,000	550,000	512,000	320,000	175,000	468,000
EUGLENOPHYCEAE																		
Euglena	6	70	246	62	63	58	65	138	446	161	119	6,600	6,600	1,600				23
Phacus	2	51	70	21	11	37	35	29	336	6		27						
Trachelomonas		255	421	178	255	157	102	6	121	106	24	830	1,600					
DINOPHYCEAE																		
Peridinium				3														
Ceratium							1			1								
PROTOZOA																		
Difflugia				8	2	1	5				1							1
Arcella																		1
Centropyxis			1															1
Vorticella				2						2	2	12						
ROTIFERA																		
Keratella		1	1	2	5	9	7	1	1	6	11							
Polyarthra			1	2														
Trichocerca																		
Brachionus		2	1	4			1			2								1
Others				1			1			7	7							
COPEPODA																		
Cyclops																		4
Juveniles				1		1	1		1									
CLADOCERA																		
Daphnia																		1
Bosmina																		

*See table 29 for description of stations.

Table 34. James River Basin - Distribution of plankton organisms, James River, September 1951. Numbers are per milliliter.--Continued

Station Nos.* (Cont'd)	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	[illegible]	35 9-29-51
MYXOPHYCEAE																		
Oscillatoria					63		3,000	25	150	1,600			28	1			232	
Aphanizomenon	2,000	510	480	3,000	15,000	12,000	15,000	12,000	12,000	5,000	6,600	8,000	13,000	6,600		3,000	22	287
Anabaena	1						1		1	1		6	1	1				
Microcystis																		
Merismopedia			1						1	2		1		2	1	1		
BACILLARIEAE																		
Melosira	357	726	976	985	987	583	153	215	317	207	199	223	284	242	26	48	9	363
Gyrosigma	2,800	157	105	217	254	140	51	46	51	26	5	15	38	15	368	9	1	
Cyclotella	612	735	97				1,600	3,000		1,600	1,600							27,000
Synedra	1,300	20,000	35,000	18,000	8,000	17,000	7,000	10,000	7,000	5,000	5,000	16,600	10,000	15,000	39	3,000		9,000
Rhizosolenia	5,700	5,000	6,600	8,000	15,000	1,600	1,600	537	1,400	3,000	8,000	5,000	8,000	5,000	106	685		8,000
Surirella			1	2			2		2									
Others	1,634								1								313	
CHRYSOPHYCEAE																		
Chromulina							1		1			3	1	1				
CHLOROPHYCEAE																		
Volvocales	5,000	15,000	5,000	8,000	3,000	1,600	8,000	23,000	12,000	7,000	5,000	10,000	25,000	15,000	17,000	25,000		20,000
Chlorococcales																		
Pediastrum					1			3	2		1		4	6	1			6
Scenedesmus	51	71	34	20	29	13	1,600	107	21	23	12	34	82	172	19	97	25	1,600
Closteriopsis	6	13	55	19	12	6	19	16		27	13	36	37	47	48	16	2	44
Actinastrum	47	31	10	5	4	2	11	5	20	10	5	13	10	48	9	11	11	385
Others	270,000	316,000	373,000	470,000	128,000	127,000	100,000	132,000	132,000	125,000	173,000	277,000	510,000	668,000	373,000	187,000	75,000	682,000
EUGLENOPHYCEAE																		
Euglena	55	204	77	39	97	67	19	60	78	48	7	54	66	100	272	12,000	77	481
Phacus	5	6	5	10	11	10	9	7	17	7	4	23	31	66	20	7	1	4
Trachelomonas	26	234				2			1	4	1	3	10	24	10	1,775		285
DINOPHYCEAE																		
Peridinium																		
Ceratium																		
PROTOZOA																		
Difflugia	2	1						1	1					3	3	4		
Arcella																1		
Centropyxis																		
Vorticella																		
ROTIFERA																		
Keratella		1	1	1	1	2			4	1	2				1			
Polyarthra					1									1	3			
Trichocerca																		
Brachionus	1		1	2					1									
Others	4	1	1			1												2
COPEPODA																		
Cyclops						1												
Juveniles	1	1			1	1	4	1		1	1	1	2		3			
CLADOCERA																		
Daphnia																		
Bosmina	1																	

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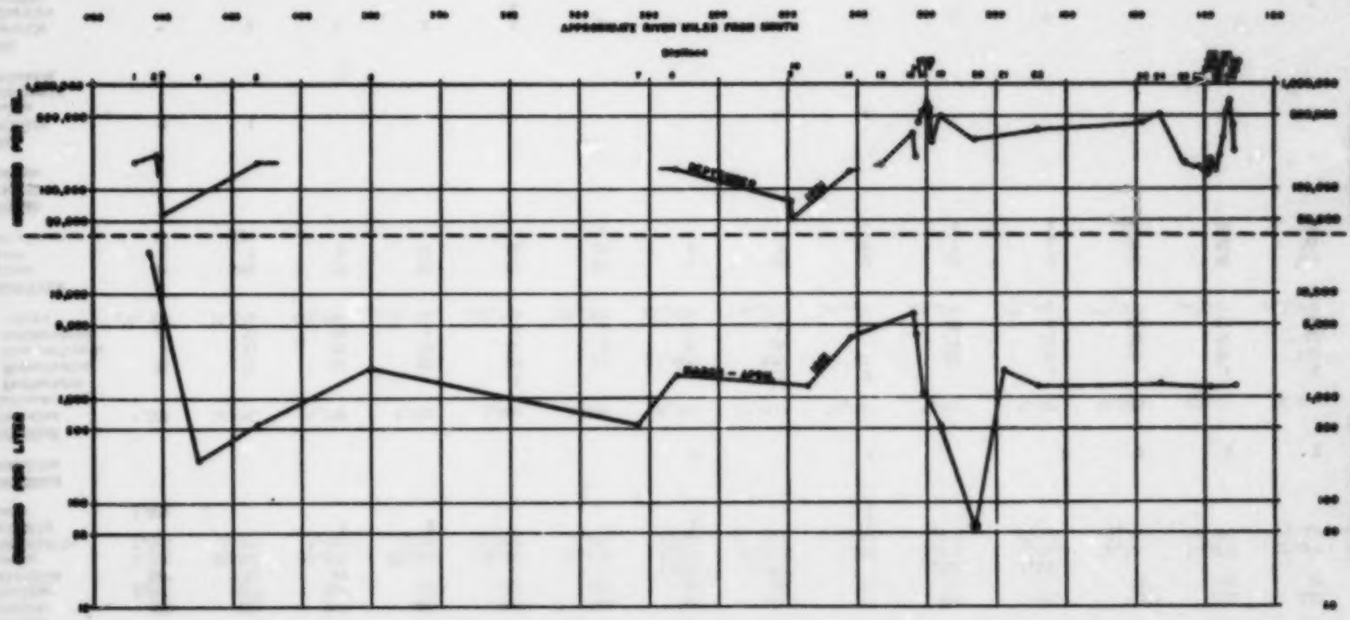
*See table 29 for description of stations.

FIGURE [illegible]



JAMES RIVER BASIN
PLANKTON DENSITIES
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL

of pollution, i.e., at Huron and Mitchell, was the flagellate *Chromulina*, but in the James there appears little reason to attach any special significance to its role as an indicator organism. Chlorococcales, a group of the green algae, comprised the dominant group at the majority of stations, being outnumbered in only one instance by the diatom *Rhizosolenia* at Station 11. Most groups achieved their maximum production after receiving the stimulus of nutrients contained in sewage discharges, although time of reaction was not uniform among various forms. *Euglena*, following a rapid increase just below the Huron outfall, disappeared from the river at Station 18, and then, conversely, showed a gradual increase with distance below entrance of Mitchell sewage that culminated in a sudden outburst at Station 36. The early effects of Mitchell wastes appeared to be suppression of planktonic metabolism rather than eradication of the organisms. Considerable variation in densities of other groups indicated that entrance of sewage effluent was one of several features influencing plankton in the James.

APPENDIXES

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APPENDIX A

MEMORANDUM OF UNDERSTANDING RESPECTING
JOINT PROGRAM FOR PUBLIC HEALTH
INVESTIGATIONS OF THE
JAMES RIVER BASIN

1. AUTHORITY--THIS MEMORANDUM OF UNDERSTANDING, made and entered into this 8th day of January, 1951, in pursuance of the Act of Congress approved June 17, 1902 (32 Stat. 388), and acts amendatory thereof or supplementary thereto, all of which acts are commonly known and referred to as the Reclamation Laws, particularly the Act of Congress approved August 4, 1939 (53 Stat. 1187), and the Act of Congress approved December 22, 1944 (58 Stat. 887), as amended; and the Act of Congress approved September 6, 1950, (Public Law 759, 81st Congress) designated General Appropriation Act, 1951, Act of Congress approved June 30, 1932 /Sec. 601/(47 Stat. 417, 418) known as the Economy Act, as amended, by and between the BUREAU OF RECLAMATION and the PUBLIC HEALTH SERVICE.

2. PURPOSE--The Bureau of Reclamation is now engaged in comprehensive development of the Missouri River Basin Project. In this connection, it is necessary to procure a report based on public health studies in the James River Basin to secure data for use in providing for maximum water utilization as a part of the Missouri River Basin Project. This work is recognized as being an integral part of the over-all Basin program and as such it is deemed the responsibility of the Bureau of Reclamation to assure its accomplishment. The work will include determinations of public health benefits from water releases and will pertain to uses of stored water for public health purposes, giving due recognition to potential revenues therefrom. The boundaries of the area covered by this memorandum shall be those defined as the James River Drainage Basin by the Geological Survey.

3. RESPONSIBILITY FOR PREPARATION OF REPORT AND SCOPE OF REPORT AND STUDIES IN CONNECTION THEREWITH--The development and preparation of a report based upon public health studies of the James River Basin is recognized to be within the particular competence of the Public Health Service. The scope of such report and studies thereunder shall include: (a) the extent, types, and major sources of pollution; (b) a review of existing laws and pending legislation regarding pollution of public waters in the States of North Dakota and South Dakota; (c) minimum stream flows necessary for public water supplies and other miscellaneous purposes, and for sanitation purposes as related to present and possible future pollution; (d) quality of water for municipal requirements and other miscellaneous purposes; (e) public health benefits of water pollution abatement resulting from the conservation, regulation, and use of water supplies under the Missouri River Basin program; (f) recommendations for pollution abatement and existing plans therefor; (g) effect of current and possible future pollution on water to be used for irrigation; and (h) other public health considerations of the water development program in the Basin.

In consideration of the premises and the mutually dependent promises of the parties hereto, it is agreed as follows:

(a) The Public Health Service shall assume full responsibility for the preparation of a complete report based upon the agreed public health studies of the James River Basin which are to be conducted by it. Such studies shall begin as soon as practicable upon the first day of the month following the date of final approval of this memorandum. The report, including findings, conclusions and recommendations, will be submitted in preliminary draft for review and comment by the Bureau of Reclamation, the Fish and Wildlife Service, the National Park Service and the Public Health officials of the States of North Dakota and South Dakota as soon as practicable after the completion of pertinent field work.

A progress report, based upon field evaluations, will be submitted not later than March 1, 1951, an interim report will be made by September 1, 1951, and a final comprehensive report will be completed not later than December 31, 1951.

The Public Health Service will in the future keep abreast of the water resource development program in the area covered by this memorandum and will continue to advise the Bureau of Reclamation on the public health aspects therein. Fifty copies of each such draft will be submitted to the Bureau of Reclamation for distribution and use.

(b) In connection with the studies contemplated herein, the Public Health Service, cooperatively with the several State health departments, will furnish personnel and equipment as necessary. Coordination of this cooperative arrangement will be accomplished by the Public Health Service.

(c) The Bureau of Reclamation shall pay, in advance, the sum of Seven Thousand, Two Hundred Dollars ($7,200.00) to the Public Health Service for providing the report and advice herein referred to. However, should the actual costs incurred by the Public Health Service be less than such sum, any unexpended or unobligated balance shall be returned to the Bureau of Reclamation in accordance with established fiscal procedure. Transfer of funds will be made by the Bureau of Reclamation in pursuance of the Act of Congress approved June 30, 1932, [Sec. 601] (47 Stat. 417, 418) known as the Economy Act, as amended. The Public Health Service shall, at appropriate times, furnish the Bureau of Reclamation with statements of expenditures relating to the actual costs incurred by it in the performance of the services herein provided for, it being understood that in no event shall the liability of the Bureau of Reclamation hereunder exceed the said sum of Seven Thousand, Two Hundred Dollars ($7,200.00).

(d) The Bureau of Reclamation shall furnish for the use of the Public Health Service in connection with the work as outlined such of the following as may be required:

(1) Limited drafting assistance by its regular staff as can be made available and as time permits.

(2) Maps, charts, hydrologic and other available data.

IN WITNESS WHEREOF, the parties hereto have caused these presents to be executed in duplicate the day and year first above written.

BUREAU OF RECLAMATION

By (Signed) K. F. Vernon

Regional Director
Region 6
Billings, Montana

Date Jan. 10, 1951

PUBLIC HEALTH SERVICE

By (Signed) Glen J. Hopkins
Glen J. Hopkins
Officer in Charge
Division of Water Pollution Control
Missouri Drainage Basin
Kansas City, Missouri

Date Jan. 8, 1951

APPROVED:

By (Signed) J. W. Mountin
Assistant Surgeon General
Acting Chief, Bureau of State Services

Date Jan. 11, 1951

APPENDIX B

FLUORIDE, NITRITE AND NITRATE IN WATER SUPPLIES OF THE JAMES RIVER BASIN

General

Adequacy of ground water is of primary concern in the James River Basin since surface supplies are used by only three municipal systems to provide domestic and industrial water and two communities use surface sources for fire fighting. Analyses show ground water supplies to be high in total solids, alkalinity, sulfates, iron, manganese, fluorides, chlorines, and hardness. In general it can be concluded that many of these supplies are unsatisfactory for human consumption, while some may actually be harmful. The exceedingly costly treatment requirements for improving available waters indicate that searching for readily obtainable and better supplies may be a more practical approach.

Rosenau[1] states: "A complete estimate of the sanitary quality of drinking water can be given only after: (1) examination of the laboratory, (2) inspection in the field, (3) experience acquired from actual use of the water. Information obtained from any single one of these three sources does not furnish complete evidence upon which final judgment can be founded or future predictions safely made.

"The clinical result from protracted use is in a sense the final test of fitness. It furnishes past proof of the effect upon health in so far as clinical symptoms are recognized, but medical science is constantly discovering new causative agents of disease, living and inert, and placing new emphasis upon previously neglected conditions of health. As a consequence, standards of fitness for drinking water tend constantly to become more rigorous. Therefore, it is necessary to have the fullest possible information from laboratory and field upon the constituents of the drinking water used in any community in order to determine if this important article of diet is concerned with the new knowledge. Also, what is more important, past fitness gives no indication of deteriorating quality and threatening danger. Inspection and analysis furnish prior warning of this."

Recent public health developments have dealt with relationships of nitrates in water to methemoglobinemia, fluorides to mottled teeth, and the public health effects and economics of a limited if not poor water supply.

Fluoride

The role of fluoride as the causative agent of dental fluorosis has been recognized since 1931[2], although a description of the lesion was reported 30 years previously. Fluorosis produces chalky-white spots or causes entire crown surfaces of the teeth to turn chalky white. As fluoride concentrations increase, secondary, brown or black stains appear; and in the severest cases the enamel shows a pitted and eroded surface which chips and crumbles easily, giving a degree of enamel attrition not commensurate with the chronological age of the individual affected.

Fluorosis becomes evident in children if, during the period of enamel calcification, they have been consuming water which contains more than 1.5 ppm. of fluoride ion. The effects of fluoride concentrations in water will differ, of course, as the amounts of water consumed and the susceptibility of individuals vary. The lesion becomes more severe as the concentration of fluorides increases, until at 6.0 ppm. practically all children are affected, many with a marked to severe type causing considerable disfigurement.

On the other hand, it has been shown that 1.0 ppm. fluoride naturally occurring in water is sufficient to decrease the incidence of dental caries by more than 60 percent. The accompanying degree of fluorosis is negligible.

Analyses completed in 1949 and 1950 (table 35 and 37) showed that of the waters at 46 municipalities in South Dakota, 24 contained fluoride in excess of the normally accepted standard of 1.5 ppm.

As early as November 1, 1929, Dr. William G. Movius, dentist of Lidgerwood, North Dakota, suspected that mottling of children's teeth might be caused by artesian water from the Dakota sandstone, and by November 29, 1929, Dr. Movius was convinced that the dental malady was definitely associated with artesian drinking water. In 1934 a survey of artesian waters under the auspices of the State Geological Survey and the Federal Emergency Relief Administration included a fluoride survey in the Dakota sandstone and Red River Valley artesian areas. It was later extended to cover the entire State of North Dakota. Fluoride concentrations in waters used by North Dakota communities in the James Basin are presented in tables 36 and 37. In parts of Stutsman, LaMoure, and Dickey Counties fluoride concentrations of three or more ppm. were recorded. Near Lidgerwood in the Sheyenne River Basin the fluoride content was the highest observed, one sample showing about nine ppm.

Table 35. James River Basin - Fluoride and nitrate determinations[1] - South Dakota

Municipality	Fluoride as F	Nitrate as N
Aberdeen	0.3	0.0
Alexandria	1.0	0.8
Alpena	2.4	0.0
Andover	0.5	0.0
Bridgewater	0.2	0.0
Britton	3.0	0.0
Carthage	3.0	0.0
Cavour	1.8	1.0
De Smet	0.2	0.5
Doland	2.8	0.0

Table 35. James River Basin - Fluoride and nitrate determinations[1] - South Dakota (cont'd.)

Municipality	Fluoride as F	Nitrate as N
Esmond	2.7	1.0
Ethan	2.4	0.0
Faulkton	2.8	0.0
Frederick	0.4	0.0
Freeman	0.4	0.0
Gayville	0.4	0.0
Hecla	5.0	0.0
Hitchcock	3.0	1.0
Howard	0.7	1.0
Huron	0.3	0.0
Ipswich	3.[illegible]	1.0
Iroquois	2.4	1.0
Langford	8.0	0.0
Leola	2.4	1.0
Lesterville	0.1	0.0
Mansfield	1.3	1.0
Mellette	2.6	0.0
Menno	2.8	1.0
Miller	2.1	0.0
Mission Hill	2.8	1.0
Mt. Vernon	1.0	0.7
Orient	3.0	0.0
Parkston	0.8	0.0
Pierpont	5.4	1.0
Plankinton	1.5	1.0
Ree Heights	0.2	0.0
St. Lawrence	1.2	0.0
Scotland	0.4	0.0
Spencer	0.5	0.0
Stickney	1.2	0.0
Tulare	1.2	0.0
Virgil	2.8	1.0
Wagner	1.2	0.0
Wessington	0.4	0.0
Wolsey	2.6	0.0
Woonsocket	1.6	0.0

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[1] Data from Division of Sanitary Engineering, South Dakota State Department of Health.

Note: Analyses made in 1949 and 1950.

Table 36. James River Basin - Fluoride determinations* - North Dakota

Municipality	Fluoride ppm.
Ludden	3.6
Ellendale	3.2
Forbes	1.8
Fullerton	2.4
Dickey County well	2.8
Dickey County well	1.6
Dickey County well	2.0
Steegewell (Stutsman County)	1.6

*Data from U. S. Geological Survey Water Supply Paper 889-A.

Comparison of analytical results supplied by county dental surveys showed a correlation that was complete and convincing. In every instance where mottled enamel was reported as general and severe, waters showed high fluoride content. In certain localities within the artesian area where shallow fluoride-free water was used, mottled enamel was observed only among those who had moved into these districts from artesian water regions.

At Britton, South Dakota, fluorosis was present in almost all of the children at an early age. A program was initiated to remove tooth damaging fluoride from the water in excess of the amount which normally inhibits decay. Fluorides are reduced from about 6.7 ppm. to 1.5 ppm. or less in treated water delivered to consumers. Reportedly, cost of the over-all installation was in excess of $30,000. Fluoride removal at Bartlett, Texas, cost 0.53 cents per 1,000 gallons per ppm. removed, (unpublished data).

Cost of applying sodium fluoride to water to achieve optimum concentrations varies with size of installation and chemicals used. Ten cents per capita may be used as a representative figure in estimating fluoridation costs.

It has been estimated that $4.00 per capita yearly is actually spent for dental care while $12.00 is required to provide adequate dental protection. The difference between 10 cents and $4.00 to $12.00 is enough to warrant serious consideration of fluoridation as a supplemental aid to dental care.

Nitrites and Nitrates

Nitrites rarely accumulate to any extent in water since they represent a transition stage between ammonia and nitrate. Nitrites indicate incomplete oxidation of protein matter and, possibly, bacterial pollution. Significance of nitrites varies with the amount, source, and relation to other constituents in the water, being highest when ammonia nitrogen is high and nitrate nitrogen low.

Nitrates represent the final stage in mineralization or oxidation of nitrogen compounds and are therefore a measure of the original quantity of organic matter with which a water was associated. Underground water from deeper sources (100 feet or more) carries from 5 to 8 ppm. nitrate nitrogen and shallow sources (10 to 30 feet--usually private wells) situated in highly cultivated grounds frequently yield water having as much as 20 to 50 ppm. Extreme figures of 550 ppm. have been recorded. Nitrate contained in well waters is largely the result of biological activities in surface layers of the soil, enhanced by cultivation and application of fertilizers. It is not always produced from animal wastes. Streams may, however, receive substantial amounts from well-nitrified sewage effluents whose content of nitrate nitrogen will range between 15 and 30 ppm.

Nitrate in surface water is a nutrient for biological activity. In an impounded water the lower the level of all forms of nitrogen the better is the general character of a supply. Turneau and Russell[3] state: "Because of the occurrence of deposits of nitrate nitrogen in certain areas of the earth's surface, and because of the constant presence in most soil to the extent of 5-100 ppm., the mere presence of small amounts (up to probably 5 ppm.) of nitrogen in well and spring water should not be considered sufficient reason for the condemnation of the supply, especially if the bacteriological evidence is negative. Since nitrate nitrogen occurs in oxidized sewage effluents in amounts as high as 20 ppm. and higher in soil leachings from around manure piles and privies, it seems reasonable to consider the presence of nitrate nitrogen above 5 ppm. as indicative of dangerous pollution."

Infant Cyanosis

Infant cyanosis was generally accepted as being due to congenital heart defect, thus nitrate poisoning, a cause of infant cyanosis, was overlooked because symptoms resembled those of babies afflicted with heart defects. The medical explanation of nitrate poisoning dates back to 1928. At that time it was known that nitrate reduced to nitrite in the body would combine with the red oxygen-carrying blood compound. The skin would then attain a greyish-blue color.

Observations of an Iowa physician[4] in 1945, with respect to the relationship between cyanosis of infants and nitrates in water, led to the suggestion of an upper nitrate limit of 10 ppm. in Iowa water supplies.

In Minnesota data compiled by the State Department of Health[8] bear out the fact that waters containing 10-20 ppm. of nitrate induced methemoglobinemia in infants two months old and younger. The linking of nitrates and cyanosis is infants aged six months or under, and the nonsusceptibility of older children and adults, led to additional investigations. Numerous cases in Iowa have opened the field to a more definite recognition of the cause and effect of infant cyanosis. Walton[7] reports that in the period 1947-1949 nine cases and one death occurred in North Dakota.

Thirteen cases in Nebraska[6] have been accepted as being due to the ingestion of nitrate in the formula concocted with well water.

There is a possibility that more complete epidemiology would add to this total. It is important to note that data in the examination of the 13 cases included analysis of the water used which showed a range of nitrate nitrogen from 36 to 200 ppm. South Dakota[9] has reported several cases of methemoglobinemia.

In Missouri, in 1948, studies with two groups of infants brought out the fact that infants with gastric acidities of pH 4.0 or above and nitrate-reducing bacteria in the upper intestinal tract developed infant cyanosis upon drinking water containing nitrates. Infants possessing a gastric acidity with pH less than 4.0 did not develop cyanosis despite the fact that they were fed water of high nitrate content. Nitrate when introduced into the colon, which always contains nitrate-reducing bacteria, irrespective of the gastric pH, caused cyanosis. This experiment showed that nitrate-reducing bacteria do not find favorable conditions in an acid environment; nitrite is not formed and therefore can not combine with hemoglobin to form methemoglobin with resulting skin discoloration.

Occurrence of Nitrates

Fair[5] mentions that nitrates in surface waters come largely from the soil where there is constant mineralization of nitrogenous organic matter. The nitrate content of water which has undergone heavy pollution with soil washings or human wastes far upstream may be several parts per million.

Large amounts of nitrates, varying from 1.0 to several ppm., may be found in shallow ground waters which receive local pollution. Another source of nitrate may be oxidation of soil nitrogen. Other factors remain to be established in determination of high nitrate contents of deep well waters in locations where sources of contamination have not been determined.

Nitrate concentrations of South Dakota water supplies are given in tables 35 and 37. The North Dakota State Department of Health[10] has an established program for nitrate analysis of water samples submitted from rural areas. Health authorities recommend that approved methods for the protection of wells be followed to preclude entrance of surface wash, including barnyard wastes. North Dakota has found no correlation between bacteriological quality and nitrate content of water. Very high nitrate content has recently been shown to exert toxic effects on artificially fed infants when present in waters used for reconstitution of dried milk foods. A check for nitrate content before water is used to supplement milk formula fed to infants is recommended.

The public health significance of methemoglobinemia has increased and is reflected in recent investigations. In North Dakota, State Department of Health laboratories have maintained a constant record of nitrate concentrations in various waters for the past five years.[11] Analysis of 950 samples reveals: approximately 43 percent of very shallow wells (10 to 20 feet deep) have excessive nitrate contents. The number of wells with high nitrate decreases uniformly as depth increases. Eight percent of wells 105 to 125 feet deep contained nitrate in excess of 10 ppm., indicating introduction to well waters by percolation. Data showed maximum amounts of nitrate appeared in water during periods of heavy runoff and minimums during times of droughts or extreme cold. Twenty-five percent of all private water supplies in North Dakota contain 10 ppm. or more of nitrate nitrogen.

Summary

Analyses of waters used in 24 municipalities in South Dakota and 8 in North Dakota showed excessive fluorides.

Nitrates in waters have been found to cause methemoglobinemia in infants aged six months and less.

The epidemiology of infant cyanosis indicates a greater incidence of nitrate poisoning than indicated by reported cases.

No direct relationship has been found between bacterial contamination and high nitrate content of water supplies, and satisfactory reports of bacteriological examinations of water do not indicate such waters to be free of high and possible harmful nitrate concentrations.

A maximum figure of 10 ppm.[7] has been suggested as the upper limit of nitrates in well waters to be used in infant feeding. Boiling waters containing low nitrate content will result in a higher nitrate concentration, thus tending to render the water nocuous.

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Table 37. James River Basin - Chemical analysis - public water supplies[1]

City	Source	Date	Solids	Na	Ca	Mg	NO_3 N	F	Cl	SO_4	P alk.	M alk.	Fe	Mn	Hardness	Misc.
South Dakota																
Aberdeen	Raw	12/49	448	98.4	61.6	34.9	0	0.5	73.9	166.4	0	289	0.1	0	298	
	Treated	12/49	411	102.2	34.3	31.1	0	0.3	73.9	147.8	18	71	0	0	86	
	Raw	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	Treated	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	Raw	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Alexandria	City well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Alpena	Artesian	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Andover	Shallow well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
~~Armour~~	Well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Artesian	Well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Ashton	Well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Bath	Well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Bonilla	Dug well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	Middle well	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Bridgewater	Well (S. Bay)	[illegible]	1368	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Bristol	Well (North)	[illegible]	1795	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	Well (South)	[illegible]	1606	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Britton	Golf course well	12/41	459	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	335	2.0	[illegible]	[illegible]	
	New well	6/47	2553	888	27	8	-	[illegible]	330	1100	0	356	0.1	0	100	
	Raw	12/49	2538	753.6	27.2	4.4	0.3	6.0	303.3	1123.1	0	280	0.04	0	86	
	Treated	12/49	2214	767.7	21.4	4.9	0	2.2	321	1121.6	0	278	0.2	0	34	
Carthage	City well	7/49	2217	-	20.1	19.4	0	2.8	298	998	0	278	0.3	0	198.5	
Cavour	Well	3/38	2044		50	18	0	1.6	99	1304	0	212	0.3	0	202	
Claremont	Well (Artesian)	4/38	2534		19	2		5.0	322	1106	0	104	0.5	0	53	
Clark	Well	7/37	1109		170	53		0.1	68	365	-	-	-	-	663	
	Well (Shallow)	7/39	1051		124	59		0.1	61	148	0	376	0.3	0	553	
Columbia	Artesian	4/37	2334		-	-		4.5	-	479	0	451	-	-	-	
Conde	Well	3/38	2348		12	2		4.0	368	1098	0	316	0.1	0	37	
Cresbard	Well, old	6/38	2130		31	17		2.4	378	380	0	486	1.2	0	168	
	Well, new	6/38	2147		25	11		2.4	586	348	0	604	3.3	0	112	
Doland	Well	7/37	2329		9	4		3.2	365	938	6		-	0	38	
Emery	City well	10/40	1608.5	60.4	-	-	-	1.1	13	528.8	0	386	1.75	0.4	1040	
	Old well	5/50	1877	-	-	-	-	0.9	12.1	-	0	433	22	-	-	
	New well raw	5/50	2829	-	-	-	-	0.9	12.1	-	0	436	30	-	-	
	New treated	5/50	2785	-	-	-	-	0.9	13.4	-	0	402	4	-	-	
Ethan	Well	3/40	2207		333	80		1.5	140	1126	0	146	3.0	0	1168	
Faulkton	Well	10/37	1966		25	19		2.8	367	929	0	-	0.8	0	141	
	-	7/50	1990	897	22	9.9	1.5	2.8	365	478	0	471	0.1	0	96	Calcium 96
	-	9/50	2022	644.4	22.9	9.6	0	2.8	308.8	483.4	0	471	0.7	0	98	pH 7.7
Fedora	Artesian	5/41	2275		10	4		5.0	200	1076	21	117	0.3	0	44	
Forestburg	Flowing well	4/37	2050					2.4		1201	0	118		0.1		
Frankfort	3 wells	7/39	2097		37	15		1.2	227	997	0	208	1.5	0	129	
Frederick	Well	4/38	662		50	22		0.8	232	86	0	310	0.8	0.4	216	
Groton	Well (city)	3/38	2202		52	5		2.4	157	1228	0	134	0.1	0	168	
	Well (N.P.)	3/38	2200		35	10		2.4	142	1205	0	162	0.3	0	128	
	Reservoir well	10/41	2248	-	-	-	-	-	132	-	0	152	-	-	-	
	North well	10/41	2204	-	-	-	-	-	112	-	0	146	-	-	-	
	Well	7/50	2146	533	49	20.3	0	2.4	104	1148	0	138	0.6	0.3	297.3	
Hecla	Artesian	4/38	3962		42	18		5.5	367	1377	0	258	1.7	0	182	
	City well	4/38	3000	965.5	54.3	5.2	1.3	5.0	375	1407.9	0	255	0.12	-	157	
Highmore	Wells	1/38	418		77	23		0.3	10	86	0	228	[illegible]	0	388	
Hitchcock	Artesian	5/38	2195		348	88		2.8	88	1261	0	126	0.3	0	1231	
Howard	Well	5/38	2102		205	58		1.6	65	1177	0	290	0.2	0.9	790	
Huron	Well (Shallow)	3/38	1108		79	43		0.8	36	351	0	476	1.5	0.3	202	
	City well	3/40	1770	160.5	205.1	129	1	0	218	514.7	0	532	0.3	0	1031.8	
	City supply	2/42	708	-	-	40	-	-	78	-	44	104	0	-	178	pH 9.9
	James River raw	2/50	1493	181.8	125.8	81.3	0.6	0.8	117.5	483.8	0	488	0	0	648.2	
	" " treated	2/50	1485	205.7	123.6	80.4	0.2	0.8	122.3	507.3	0	444	0	0	649.4	
Interior	Well	10/37	724		18	4		0.8	11	200	0	327	[illegible]	0	61	
Ipswich	Well	5/38	2129		342	95		2.8	50	1267	0	144	0.8	0.1	1247	
Iroquois	Artesian	5/38	2096		10	8		2.4	158	1067	0	234	0.1	0	58	
Lane	Well (flow)	4/37	2077					2.6		1232		115				
Langford	Artesian	4/38	2695		27	2		5.0	228	1215	14	403	0.1	0	49	
Leola	Artesian	4/30	2191		19	6.0		2.2	556	324	0	524	0.5	0	70	
Lesterville	Well	1/40	625		132	47		0.8	18	134	0	368	5.0	0.05	531	
Mellette	Well (new)	1/39	803		5.0	2.5		0.4	3.0	155	0	499	2.4	0	27	
McLaughlin	Well (east)	9/37	745		37	35		0	5	125	0	313	4.5	0.2	287	
McLaughlin	Well (west)	9/37	381		54	37		0	9	51	0	274	2.5	0.2	287	
Menno	Old well	6/47	-	-	-	-	-	2.8	119	-	0	154	3.5	-	-	Soap hardn. 1320
	New well	6/47	-	-	-	-	-	1.2	68	-	0	170	0.5	-	-	" " 880
	Old well	6/49	2319	-	395	83	-	2.5	126	1242	0	142	0.9	Tr.	1327	Silica 10
	New well	6/49	1367	-	133	34	-	1.0	25	754	0	190	0.8	1.3	472	Silica 31
	Artesian	9/36	2209		394	88		2.8	129	1231	0	120	2.8	0.2	1350	
Miller	Well	6/38	2120		192	58		2.4	99	1214	0	134	1.0	0	721	
	New well	5/41	2234	-	-	-	-	2.5	-	-	0	144	-	-	70.8	
	New 1250'	6/41	2277	-	-	-	-	2.4	-	-	6	146	-	-	802	
	New well	6/41	2240	-	-	-	-	2.5	-	-	6	146	-	-	890	
	Artesian w.	5/42	1710	-	-	-	-	2.8	208	-	0	296	-	-	-	
	Well water	10/43	2164	-	231	65.5	-	2.8	91	1210	0	140	0.2	0	848	Silica 14
Mission Hill	Well	1/40	2243		359	75		2.5	121	1026	0	134	5.0	0	1213	
Mitchell	Lake raw	Aug. '41	325		69	28		-	20	128	0	190	[illegible]	0	260	
	Treated (comp)	Aug. '41	290		31	10			20	110	21	43	-	-	143	
	Raw	Aug. '41	310-340	-	60-75	25-30	-	N.D.	15-25	120-135	0	140-160	2 or less	-	250-270	
	Treated	Aug. '41	270-310		27-35	8-13	-	N.D.	15-25	100-120	27-25	35-50	N.D.	N.D.	135-150	

Table 37. [illegible] - Chemical analysis - public water supplies[1]—Continued

South Dakota (Continued)

[illegible]

North Dakota

[illegible]

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[1] South Dakota data from South Dakota State Department of Health.
North Dakota data from North Dakota Geological Survey, Bulletin 11.

APPENDIX C

PARTIAL REVIEW OF LITERATURE ON PUBLIC HEALTH ASPECTS OF IRRIGATION WITH SEWAGE POLLUTED WATER[1]

1. Davidson (1), according to Wilson (9), reports an outbreak of typhoid and paratyphoid fever involving 65 cases in North Battleford, Saskatchewan, Canada, during the summer of 1941. Neither milk nor water could be incriminated as the agent of transmission. Inconclusive evidence indicated that the infection was spread by vegetables which were irrigated, and possibly washed, with water from a ditch into which the sewage works discharged its effluent.

2. Chapman (2), stresses the need for treatment of sewage discharged to streams from which water is taken to irrigate market produce. Investigations conducted by the Colorado State Board of Health have shown that vegetables, grown in fields many miles below the source of the pollution, contained large numbers of colon bacilli. In many instances washing could not make them fit for human consumption. Some epidemiological evidence is presented. The death rate for typhoid fever, also for diarrhea and enteritis in infants up to 2 years of age, in Colorado is high when compared to that for the U. S. and several western States. Colorado counties having polluted waters have death rates for the above infections almost twice those of counties in which there is little or no pollution of streams. Maps are presented which show the grossly polluted streams are closely associated with the counties having these higher death rates. Water and milk were not considered the infection source. It was recommended that fruits and vegetables grown under or close to the ground should not be irrigated with sewage polluted water. Although cooking may make eating such vegetables safe, it does not eliminate the possibility of introduction of infectious matter into the kitchen and its transfer to foodstuffs.

3. Lumsden and Anderson (3), in their investigation of the origin and prevalence of typhoid fever in the District of Columbia, found (3a) "A suggestively large portion of the typhoid cases in the District of Columbia had eaten lettuce, celery or strawberries during the 30 days prior to illness." They experienced difficulty in tracing the produce back to its source and therefore considered definite conclusions "not justifiable." They conclude (3b), however, that "In view of the insanitary conditions, particularly in respect to the lack of sanitary privies on farms which supply a large portion of the green vegetables and fruits distributed in Washington, it seems quite probable that those foodstuffs play some part, and for occasional periods perhaps a very considerable part, in the distribution of typhoid-fever infection in the District of Columbia." Furthermore, they recommend (3c), "The enactment of legislation prohibiting the sale or the offering for sale in the District of Columbia of . . . any green garden truck

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[1] Acknowledgment is made of the use of this Review as included in the Kansas River Basin Water Pollution Investigation.

obtained from farms not provided with either sanitary privies or sanitary water-closets."

4. Bundsen (4), reports that following a typhoid outbreak in Chicago, which was eventually traced to oyster infection, special effort was made to determine the sources of certain vegetables, lettuce and watercress, served in hotels and restaurants, where it appeared the majority of cases had contracted the infection. This was found to be impossible; there was no common source for such produce. In connection with the investigation bacteriological examination of fruits, vegetables and watercress was undertaken. E.coli bacteria were found but whether of human or other source was not determined. In one case high coli contamination of lettuce was traced to the ice in which it was packed. Need for greater attention to watercress is stressed. In the discussion of Bundsen's paper Dr. F. C. Johnson, a pediatrician, comments that based on his experience he has "advised not to feed lettuce or celery to children as the possibility of infections being carried by these raw vegetables is really great."

5. In the discussion (5) of Dr. Warry's report of an outbreak of enteric disease involving 110 cases in the borough of Hackney, England, it is noted that a high percent of the cases had partaken of watercress within 3 weeks prior to the illness, and bacteriological examination of beds from which the watercress had been taken showed the presence of sewage organisms, in one case, as high as 50 E.coli bacteria per cubic centimeter of water.

6. An article in the Journal American Medical Association (6) notes the raising of vegetables, frequently eaten raw, on the Paris, France, sewage farm and associates the occurrence every year, from July to October, of typhoid fever in Paris with the marketing of these vegetables. "Claudits found germs, after several days, on green herbs thus treated which a thorough washing could not remove. Dr. E. Marchoux, after an investigation, 'recommended that the kinds of herbs and vegetables that may be grown on sewaged lands be established by law.'"

7. The American Society of Civil Engineers' committee on salvage of sewage (7) notes that in 1934 the directors of public health in each of the 48 States and the District of Columbia were asked for information on the extent of sewage use for irrigation. Only 9 States, of the 40 replies received, admitted having experience with sewage irrigation and sewage irrigated crops. Significantly, "four were able to trace illness of an epidemic order to such use, whereas one other stated that cattle, pastured on a raw sewage irrigated field developed poorly and were infested with Cysticercus bovis." At that time (7a) "Only one of the nine was agreeable to the use of (sewage) treatment plant effluent on vegetables to be eaten raw," and that State prescribed practically potable water standards for such effluent. In summarizing the committee states (7b) "Thus it would appear that, except for use upon vegetables to be eaten raw, an effluent from about that afforded by subsidence, trickling filters, and secondary subsidence effecting about 85 percent reduction in biochemical oxygen demand (B.O.D.) and suspended solids, followed by chlorination, should satisfy health requirements. . ."

8. Roberts (8) noted 23 of 45 cattle fattened on the Tucson, Arizona, sewage farm were upon slaughtering found infested with the tapeworm, *Cysticercus bovis*. Since these cattle apparently came from different sources — they all bore different brands — and such general infestation indicated a source common to all or most of them, it was concluded that the infestation resulted from drinking sewage polluted water.

9. Wilson (9) cites the experience at the Melbourne, Australia, sewage farm where in 1937, 46 percent of the cattle grazed were found infested with *Taenia saginata*. The sale of these cattle was banned. During a six month survey of Melbourne (1941-42) 100 cases of human tapeworm infections were treated. He concludes, "In . . . any town where large portions of the inhabitants are infested with tapeworm . . . sewage and sewage sludge must present a real danger."

10. Under Annotations (10) it is noted that Leptospirosis is essentially an occupational disease. Human infection is acquired through the alimentary tract or by contact with contaminated water or other material. It has occurred "during the last few years among . . . sewer workers in London and Glasgow . . ., and workers in the beet fields in Ireland, who are probably infected through abrasions of the hands in the same way as are the sugar cane cutters in Queensland."

11. Mills et al. (11) conducted laboratory investigations to determine whether the bacteria penetrated the surface of fruits and vegetables. They found that although bacteria do not penetrate the uninjured surface, they may gain entrance through damaged or decayed surfaces and remain viable for from 7 to 42 days. They also demonstrated that bacteria may persist on the surface of fruits or vegetables kept moist for 15 or more days.

12. Kligler (12) investigated the survival and dispersion of typhoid and dysentery bacilli in soil. These bacteria were recoverable from artificially inoculated moist soil (pH 6.6-7.4) for 70 or more days, but were not recoverable in dry soil on the 20th day. They penetrated to a depth of 2, but not 3, feet in 40 days in relatively porous soil under a 1 to 2 inch head of water.

13. Melick (13) in three outdoor experiments, extending from May to September, isolated typhoid bacteria from garden soil 41, 34 and 35 days after inoculation with typhoid bearing excreta. Under hot house conditions old strains of typhoid bacteria survived for 74 days in garden soil enriched with sterile sewage; fresh strains survived only 49 days. In these experiments typhoid bacteria were found on radishes grown in infected soil 37, 28 and 35 days, and on lettuce after 21 days, after inoculation of the soil. The organism became attached to the surface and was not ordinarily removable by washing.

14. Creel (14) investigated the viability of typhoid bacilli on garden truck. He reports 3 experiments in which radishes and lettuce were raised on soil sprinkled with a fecal emulsion mixed with 24-hour old culture of typhoid bacilli 2 or 3 days after the planting.

He states, "that plants cultivated in contaminated soil will take up on the leaves and stems, as they grow through the soils, organisms existing therein."

"The *Bacillus typhosus* (typhoid bacillus) was recoverable from the tips of leaves that were, to the naked eye, free from soil" and that when these vegetables were grown under natural conditions (except for the artificial inoculation of the soil) the infectious material could be isolated from the leaves up to 31 days.

"Rainfall will not free the vegetables from the infected material."

15. According to Malick (13) "Morse (15) attributed 49 typhoid cases among inmates of an insane asylum to eating of celery." Typhoid cases had occurred in the institution a few months previously, the celery bed received the institution's sewage, and the epidemic occurred soon after the first use of the celery.

16. According to Malick (13) "Pixley (16) records 2 cases of typhoid from eating uncooked rhubarb, which was grown on soil known to be fertilized with typhoid bearing excreta."

17. Veatch (17a) in discussing the Denver, Colorado, sewage disposal problem notes that on certain days the Denver sewage accounts for 97 percent of the flow of the South Platte River, which is used for irrigation immediately downstream. He refers to the construction at Denver in 1937 of a sewage treatment plant which included "fine grained rapid sand filters to secure a high rate of removal of suspended solids and incidentally the removal of ... the encysted type of amoeba (*Endamoeba histolytica*) which is strongly suspected of being responsible, through the medium of sewage irrigated vegetables, for a considerable amount of sickness in this area." (Abstractor's note: *The magnetite filters referred to did not operate satisfactorily and their use was discontinued*.)

18. Tanner (18) points out that missed cases and carriers may always be present and that sewage should always be regarded as containing infectious organisms. The work of several investigators is cited and Tanner concludes that (18a) "Sufficient data . . . have been recorded to justify the conclusion that polluted soil may infect vegetables grown on it." He adds (18b) that "good epidemiological evidence seems to exist in the literature to the effect that fresh vegetables may and have caused communicable diseases and that the sanitary condition of the soil from which they are harvested is important." - and finally (18c) that "This review of the literature quite clearly indicates that fresh vegetables which are raised on polluted soil may transmit pathogenic bacteria."

19. Rider (19) in commenting on irrigation in Arizona notes the insanitary practices of many camps of agricultural workers and the use of the main canals for drinking water, swimming, washing clothes, etc. In spite of such conditions only a few instances were noted where water-borne diseases were attributed to canal water. Several years ago, as the result of a newspaper syndicated article, the State laboratory undertook bacteriological examination of lettuce. Many heads — from 16 fields in the Salt River Valley and from two in the Eloy district — were cultured but no evidence of typhoid or allied organisms was found. Although the technique used was rather

hastily devised, it was felt any general contamination would have been indicated.

20. The Committee on Sewage Disposal, American Public Health Association (20) notes in 1937, that "California, alone, out of 33 States reporting, . . . has adopted regulations under its Public Health Act whereby the disposal of sewage, sewage effluent or sludge for irrigation or fertilizing purposes" requires a permit from the State Board of Health. Briefly these California Regulations require that raw sewage shall not be used for irrigating growing crops, and settled or undisinfected sewage is banned for the irrigation of growing vegetables, garden truck, berries, or low-growing fruit, or for watering vineyards or orchards where windfalls or fruit lie on the ground.

21. The Committee on Utilization of Sewage Sludge as Fertilizer, Federation of Sewage Works Associations, in their report (21) in 1942, notes the California regulations are still in effect. Several other States regulate or advise regarding use of sewage sludge.

22. Rawn (22) notes that as of June, 1934, 39 States and the District of Columbia had replied to a questionnaire on use of sewage for irrigation. Thirty States reported neither sewage nor sewage-polluted waters were used for irrigation within their boundaries. Seventeen of these States reported they would not tolerate such use, and the other 13 found it repugnant.

"In the 9 States which admitted use of sewage for irrigation, the attitude was one of tolerance . . . and rigid regulations of the production of the effluent as well as the nature of the crops for which it was to be used."

23. DeMartini (23) mentions the following regulations concerning irrigation with sewage and sewage-laden waters:

(1) Colorado - "Requires written permission of State Board of Health for use of sewage or sewage-polluted waters when Coli-aerogenes group of bacteria exceeds 10 per cc."

(2) California and Oregon - "Prohibit use of raw sewage for irrigating growing crops. Prohibit use of settled or undisinfected sewage effluents on growing vegetables and garden truck. Highly oxidized and disinfected sewage effluents can be used provided they meet drinking water standards in Oregon and in California if not over 10 percent of 10 cc. portions are positive for the Coli-aerogenes group. Also no single sample can be positive for over half of the 0.1 cc. portions examined."

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APPENDIX D

GENERAL DATA

Tests and their significance

Temperature - Water temperature is one of the factors which controls oxygen solubility and thus saturation level of dissolved oxygen in a stream. The rate of natural purification and bacterial growth is affected by changes in temperature.

Turbidity - Turbidity of water is due to suspended matter, both particulate and settleable or colloidal and nonsettleable. Turbidity measurements give an approximation of the amount of silt or suspended material carried by a stream. To a limited extent a correlation exists between turbidity, suspended matter, and high and low stream stages. Turbidity also results from plankton growth.

pH - pH is defined as the negative logarithm of hydrogen ion concentration. The pH value indicates relative acidity or alkalinity, with the neutral point at pH 7.0. Values lower than 7.0 indicate the presence of acids, above pH 7.0, the presence of alkalies.

Alkalinity - Alkalinity of a water usually indicates the presence of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. In comparison with pH, alkalinity is generally assumed to be a quantity factor while pH is concidered an intensity factor.

Dissolved Oxygen - Normally the amount of oxygen dissolved in stream water is limited by the saturation value (9.17 ppm. at 20° C. and 760 mm. barometric pressure) which is a function of water temperature and atmospheric pressure, but in some cases as a result of the photosynthetic action of some aquatic plants this value may be exceeded, causing supersaturation. Dissolved oxygen must be present to support fish and aquatic life and for the natural aerobic purification of stream waters, the minimum quantity permissible depending on the quality of water desired. Satisfactory methods of waste disposal to the streams depend on the relationship between character, quantity, and strength of wastes, and the character and volume of the receiving stream. Varying dissolved oxygen values below the saturation level are an indication of the presence of organic, and possibly chemical, pollution which utilizes oxygen from the stream. A measure of the degree of pollution of a particular area is given by deficiency in dissolved oxygen content below saturation.

Biochemical Oxygen Demand - The standard test for biochemical oxygen demand (B.O.D.) requires five-day incubation in total darkness at 20° C. of sealed samples of the water under examination, and determination of the loss of dissolved oxygen during that time. Where the loss may be greater than the initial dissolved oxygen present, the sample is diluted with standard B.O.D. - free dilution water and the measured loss multiplied by the appropriate dilution factor. B.O.D.

thus determined becomes a measure of the amount of oxygen necessary to satisfy the biochemical oxidation requirements of the pollution present at the time the sample was collected. Since the amount of dissolved oxygen present decreases with rising temperatures, while, at the same time, the rate of biochemical oxidation increases, critical stream conditions result during warm months, particularly when high temperatures are combined with low stream flows.

Hardness - Water is rendered hard principally by the presence of calcium and magnesium, chiefly in the form of bicarbonates and sulphates, but occasionally as chlorides and nitrates and is expressed as "carbonate" and "noncarbonate" hardness. The sum of these two is the total hardness. Hardness in waters usually has little to do with health, but becomes of major economic importance in industrial and domestic use.

Coliform Group Organisms - This determination gives the most accurate estimation of the degree of pollution by sanitary sewage. These coliform bacteria are present in the intestines of warm blooded animals and are discharged in vast numbers in human feces, which constitute the main source of these bacteria in sewage.

Laboratory Procedures

Chemical and bacteriological examinations and analyses were made in accordance with "Standard Methods for the Examination of Water and Sewage" Ninth Edition, 1946, of the American Public Health Association.

Definitions of Terms

1. Acre-foot. A volume of water equivalent to one acre in area and one foot deep.

2. Cubic foot per second (cfs) or second foot. A measure of the rate of discharge relating volume to time.

3. Population Equivalent (P.E.) 0.167 pounds of 5-day 20° C. B.O.D. per day, the amount of organic pollution usually attributed to wastes from one person.

4. Parts per million (ppm.). One part in a million parts of water by weight or 1 milligram per liter.

5. Plankton. An assemblage of microscopic organisms that live suspended in water.

6. Benthos. Animals dwelling on the bottom of various bodies of water.

7. Algae. Microscopic primitive plants other than fungi that occur in plankton, periphyton, and as floating mats. This definition has been restricted for usage in this report.

8. Monocarbonate Alkalinity. Alkalinity due to the presence of the monocarbonate (CO_3) ion expressed as ppm. calcium carbonate.

9. Bicarbonate Alkalinity. Alkalinity due to the presence of bicarbonate (HCO_3) ion expressed as ppm. calcium carbonate.

Biological Information

Fishes

1. *Cyprimus carpio* - Carp
2. *Stizostedion vitreum* - Walleye
3. *Perca flavescens* - Yellow Perch
4. *Pomoxis annularis* - White Crappie
5. *Pomoxis sparoides* - Black Crappie
6. *Huro salmoides* - Large Mouth Black Bass
7. *Ameiurus natalis* - Yellow Bullhead
8. *Ameiurus melas* - Black Bullhead
9. *Ictalurus furcatus* - Blue Catfish
10. *Eucalia inconstans* - Stickleback
11. *Pimephales notatus* - Bluntheed Minnow
12. *Schilbeodes* sp. - Madtom

Mussels

1. *Fusconaia flava*
2. *Fusconaia ebenus*
3. *Amblema costata*
4. *Quadrula quadrula*
5. *Arcidens confragosus*
6. *Anodonta grandis*
7. *Lampsilis silquoidea*
8. *Ligumia recta latissima*
9. *Obovaria subrotunda*
10. *Micromya iris*
11. *Truncilla truncata*

Plankton Organisms - September 1951

MYXOPHYCEAE

Chroococcus spp.
Merismopedia punctata Meyen
Microcystis aeruginosa Kuetziner *emend.* Elenkin
Aphanothece spp.
Coelosphaerium dubium Grunow
Coelosphaerium Kuetzingianum Naegeli
Gomphosphaeria aponina Kuetzing
Oscillatoria spp. (3)
Lyngbya contorta Lemmermann
Anabaena flos-aquae (Lyngb.)
Aphanizomenon flos-aquae (L.) Ralfs

CHRYSOPHYCEAE

Chromulina sp.
Chrysocapsa sp.

DINOPHYCEAE

Peridinium sp.
Ceratium hirundinellae (O.F.Muell.) Dujardin

COPEPODA

Cyclops sp. mostly juveniles

CLADOCERA

Bosmina sp.
Daphnia sp.

DIATOMACEAE

Gyrosigma sp.
Melosira sp.
Rhizosolenia sp.
Synedra spp. (5)
Mastogloia sp.
Surirella spp. (2)
Cyclotella sp.
Navicula spp. (3)
Cymatopleura solea (Breb.) W. Smith
Nitzschia sp.
Stephanodiscus astrea (Ehr.) Grun.
Rhoicosphenia curvata (Kuetz.) Grun.
Cystopleura sp.
Stauroneis sp.
Cymbella spp. (3)
Gomphonema sp.
Caloneis sp.

PROTOZOA

Difflugia urceolata Carter
Difflugia globula
Arcella vulgaris Ehr.
Centropyxis aculeata Stein
Didinium nasutum (Müller)

CHLOROPHYCEAE

VOLVOCALES

Chlamydomonas spp. (2)
Dysmorphococcus variabilis Takeda
Pteromonas angulosa (Lemmermann)
Pandorina morum (Muell.) Bory

TETRASPORALES

Elakatothrix sp.

CHLOROCOCCALES

Dimorphococcus sp.
Closteriopsis longissima var. *tropica* West and West
Lagerheimia subsalsa Lemmermann
Lagerheimia wratislawiensis Schröder
Crucigenia quadrata Morren
Crucigenia tetrapedia (Kirch.) West & West
Ankistrodesmus falcatus (Corda) Ralfs
Actinastrum Hantzschii Lagerheim
Pediastrum duplex Meyen
Pediastrum Boryanum (Turp.) Meneghini
Selenastrum sp.
Tetrastrum elegans Playfair
Tetrastrum staurogeniaeforme (Schröder) Lemmermann
Tetrallantos Lagerheimia Teiling
Westella botryoides (W. West) de Wildeman
Nephrocytium sp.
Micractinium pusillum Fresenius
Franceia spp. (2)
Planktosphaeria gelatinosa G. M. Smith
Coelastrum cambricum Archer
Coelastrum microporum Naegeli
Coelastrum proboscideum Bohlin
Schroederia sp.
Dictyosphaerium pulchellum Wood
Chlorella ellipsoidea Gerneck
Chlorella vulgaris Beyerinck
Scenedesmus bijuga (Turp.) Lagerheim
Scenedesmus bijuga var. *alternans* (Reinsch) Hansgirg
Scenedesmus abundans var. *longicauda* G. M. Smith
Scenedesmus dimorphus (Turp.) Kuetzing

CHLOROPHYCEAE

CHLOROCOCCALES (cont'd.)

Scenedesmus spp. (4)
Oocystis sp.
Acanthosphaeria sp.
Tetraedron spp.
Botryococcus Braunii Kuetzing

ZYGNEMATALES

Staurastrum sp.
Cosmarium sp.

EUGLENOPHYCEAE

Phacus acuminatus Stokes
Phacus longicauda (Ehr.) Dujardin
Phacus torta Lemmermann
Phacus pyrum (Ehr.) Stein
Phacus monilata Stokes
Phacus rostafinskii Drezepolski
Trachelomonas volvocina Ehrenberg
Trachelomonas Girardiana (Playfair) Deflandre
Trachelomonas hispida coronata Lemmermann
Euglena oxyuris Schmarda
Euglena spirogyra Ehr.
Euglena acutissima Lemmermann
Euglena acus Ehr.
Euglena acus var. *rigida* Hübner
Euglena caudata Hübner
Euglena viridis Ehr.
Euglena polymorpha Dangeard
Astasia sp.
Peranema sp.
Lepocinclis fusiformis (Carter) Lemmermann

ROTIFERA

Polyarthra platyptera Ehr.
Keratella cochlearis (Gosse)
Triarthra longiseta Ehr.
Lecane sp.
Brachionus spp. (2)
Trichocerca sp.

LABORATORY DATA

SUMMARY OF INDIVIDUAL SAMPLES

Sampling Point	Mileage from Mouth	Date	Avg. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkalinity p.p.m. CO_3	Alkalinity p.p.m. HCO_3	Nitrogen - N p.p.m. NH_3	Nitrogen - N p.p.m. NO_2	Nitrogen - N p.p.m. NO_3	PO_4
James River	J.R. 584	2/5/51 5:25 P	1	0	0.00	0	5.7	200	8.2	<25		458				
Above Jamestown, N.D.		2/7/51 5:45 P	1	0	0.00	0	4.1	220	8.3	<25		480				
		2/8/51 3:15 P	1	0	0.50	3	4.3	5,400	8.2	<25		344				
		2/9/51 10:40 A	1	0	0.00	0	3.6	20	8.2	<25		444				
		8/27/51 8:05 A	1	19	4.30	45	4.2	18,400	8.1	160		282				
		8/28/51 7:30 A	1	17	5.10	52	4.6	24,000	8.3	160		236				
		8/29/51 7:55 A	1	17	5.05	52	5.5	32,000	8.5	40		284				
		8/30/51 8:40 A	1	17	5.40	55	7.3	24,000	8.4	200		200				
		8/31/51 9:30 A	1	16	5.05	50	5.4	32,000	8.2	95		258				
Pipestem River	J.R. 577	2/5/51 5:00 P	0.2	1	5.70	40	2.1	450	8.2	<25		380				
Above Jamestown, N.D.	P.R. 3	2/7/51 6:10 P	0.2	1	4.65	33	2.6	450	8.3	<25		396				
		2/8/51 3:30 P	0.2	1	6.30	44	2.1	2,400	8.2	<25		360				
		2/9/51 11:00 A	0.2	1	5.90	41	2.2	110	8.2	<25		446				
		8/27/51 7:45 A	0.6	18	3.25	34	6.1	4,400	8.2	95		260				
		8/28/51 8:00 A	0.6	18	4.50	47	6.8	18,400	8.3	110		248				
		8/29/51 7:35 A	0.6	17	5.35	55	7.3	2,200	8.4	75		284				
		8/30/51 8:10 A	0.6	17	4.65	47	7.4	24,000	8.2	100		238				
		8/31/51 9:00 A	0.6	16	5.85	58	6.1	980	8.2	60		276				
James River	J.R. 526	1/14/48			0.00	0	8.6		8.2	<25						
N. of Adrian, Highway No. 46		2/21/48			0.00	0	7.2									
		8/27/48					3.5									
		3/17/50			0.00	0	7.9									
		2/5/51 3:50 P	10	0	2.00	14	1.6	200	8.3	<25		396				
		2/7/51 9:45 A	10	0	1.70	12	2.2	200	8.4	<25		416				
		2/8/51 10:00 A	10	0	2.10	14	2.6	40	8.6	<25		404				
		2/9/51 9:35 A	10	0	2.20	15	1.8	20	8.3	<25		416				
		8/27/51 6:30 A	8	17	5.30	54	5.8	2,800	8.1	110		336				
		8/28/51 6:30 A	8	17	6.20	63	6.6	18,400	8.1	100		328				
		8/29/51 6:30 A	8	16	6.10	61	5.7	1,580	8.4	95		248				
		8/30/51 9:00 A	8	18	5.90	62	7.8	1,580	8.2	120		320				
		8/31/51 7:40 A	8	15	6.15	60	7.4	2,800	8.2	85		276				
James River	J.R. 506	1/14/48			0.00	0	7.0		7.9	<25						
West of La Moure.		8/28/48					8.0									
N.D., Highway No. 13		2/5/51 Noon	18	0	1.20	8	1.9	200	8.5	<25		384				
Crossing above dam.		2/7/51 2:00 P	18	0	1.25	9	3.0	450	8.3	<25		392				
		2/8/51 11:15 A	18	0	1.90	13	1.7	230	8.5	<25		356				
		8/27/51 9:05 A	15	19	5.80	62	6.2	460	8.2	95		292				
		8/28/51 8:50 A	15	19	6.85	74	6.3	2,800	8.2	110		398				
		8/29/51 9:00 A	15	17	5.82	59	6.7	2,600	8.5	110		252				
		8/30/51 9:10 A	15	18	5.10	54	5.3	660	8.3	100		306				
		8/31/51 9:50 A	15	17	6.45	66	5.3	660	8.3	85		268				
		2/27/48			0.0	0	8.3									

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Mileage from Mouth	Date	Avg. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml	pH	Turb. p.p.m.	Alkalinity M.O. CO_3	Alkalinity M.O. HCO_3	Nitrogen - N p.p.m. NH_3	Nitrogen - N p.p.m. NO_2	Nitrogen - N p.p.m. NO_3	PO_4
James River	J.R. 516	8/27/51	15	19	6.90	76										
West of La Moure, N.D., Highway No. 13		8/28/51	15	19	7.30	79										
Crossing below dam (cont'd)		8/29/51	16	17	6.60	66										
		8/30/51	15	18	7.75	71										
		8/31/51	15	17	7.00	71										
James River	J.R. 484	10/16/46					4.7									
West of Oakes, N.D. County Road crossing		2/21/47					8.4									
		2/27/48			0.0	0	3.6									
		8/26/48					4.6									
		2/5/51 1:00 P	20	0	4.70	51	1.8	1,300	8.3	< 25		368				
		2/7/51 2:50 P	20	0	5.15	56	2.6	1,100	8.3	< 25		384				
		2/8/51 12:45 P	20	0	6.25	68	2.0	490	8.3	< 25		432				
		8/27/51 8:05 A	17	18	5.60	58	6.9	18,400	8.3	180		300				
		8/28/51 8:05 A	17	18	5.45	57	7.1	24,000	8.3	130		278				
		8/29/51 7:45 A	17	17	4.80	48	7.8	38,000	8.4	200		288				
		8/31/51 8:50 A	17	16	6.55	66	6.6	38,000	8.3	160		296				
James River	J.R. 466	1/14/48			0.0	0	6.4		8.0	< 25						
West of Ludden, N.D. Highway No. 11		2/27/48			0.0	0	7.4									
Crossing		8/26/48					5.3									
		2/5/51 2:10 P	20	0	0.00	0	3.2	1,100	8.2	< 25		508				
		2/7/51 3:25 P	20	0	0.50	3	2.8	450	8.4	< 25		448				
		2/8/51 3:30 P	20	0	1.05	7	1.7	270	8.2	< 25		496				
		8/27/51 7:25 A	18	18	6.50	68	5.4	980	8.3	110		274				
		8/28/51 7:15 A	18	19	6.30	68	6.9	920	8.3	110		288				
		8/29/51 7:15 A	18	17	6.15	63	5.8	2,200	8.4	110		268				
		8/31/51 8:35 A	18	17	5.50	56	5.5	1,580	8.2	150		260				
James River Bridge	J.R. 458	2/5/51 7:30 A	0	0	1.35	9	12.2	< 30	7.0	< 25		705				
1-3/4 mi. West of Hecla, S. D.		2/6/51 8:00 A	0	0	2.05	14	12.0	< 30	7.0	< 25		735				
		2/7/51 7:15 A	0	0	0.95	6	8.7		7.7	< 25		720				
		2/8/51 8:00 A	0	0	1.10	8	5.3	< 30	7.6	< 25		730				
		2/9/51 7:45 A	0	0	0.50	3	10.0	36	7.8	< 25		750				
		8/27/51 8:30 A	17	18	3.95	42		230	8.4	130	20	194				
		8/28/51 7:30 A	24	19	4.50	48	3.3	430	8.2	120	4	196				
		8/29/51 7:00 A	18	19	3.30	35	2.9		8.2	170	8	189	0.05	Trace		
		8/30/51 7:30 A	16	19	4.80	51	3.4	11,000	8.2	140	11	182	0.80	0.00	00.150	1.0
		8/31/51 8:40 A	21	18	4.10	43	4.0	2,300	7.8	120	0	179				
		9/1/51 6:50 A	17	17	3.45	35	4.8		7.9	130	0	181	0.40	Trace		Trace
James River - County Bridge below Sand Lake Wildlife Refuge, S. D.	J.R. 442	2/5/51 8:40 A	0	0	0.35	2	6.8	< 30	7.1	< 25		630				
		2/6/51 8:45 A	0	0	0.55	4	14.0	< 30	7.1	< 25		640				
		2/7/51 7:55 A	0	0	0.40	3	4.6		7.9	< 25		625				
		2/8/51 8:45 A	0	0	0.40	3	3.7	< 30	7.5	< 25		625				

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Mileage from Mouth	Date	Avg. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkalinity p.p.m. CO_3	Alkalinity p.p.m. HCO_3	Nitrogen - N p.p.m. NH_3	Nitrogen - N p.p.m. NO_2	Nitrogen - N p.p.m. NO_3	PO_4
James River - County Bridge below Sand Lake Wildlife Refuge, S.D.	J.R. 469	2/5/51 8:15 A	0	0	0.35	2	6.0	<30	7.7	<25		630				
		8/27/51 9:00 A	0	16	4.10	43		930	8.5	300		264				
		8/28/51 8:00 A	0	19	3.70	40	10.0	4,600	8.4	250	16	272				
		8/29/51 7:30 A	0	18	3.60	38	8.8		8.5	260	17	278	0.0	0.000		
		8/30/51 8:00 A	0	20	3.95	39	7.4	24,000	8.6	250	21	222	Trace	0.000		0.0
		8/31/51 9:10 A	0	16	5.40	54	7.3	2,300	8.5	190	18	286				
		9/1/51 7:20 A	0	16	4.70	47	8.1		8.3	210	7	276	0.10	0.005		1.5
Elm River near Westport, S.D.	J.R. 429 E.R. 27	2/5/51 9:05 A	0	0	3.95	27	1.7	30	7.2	<25		340				
		2/6/51 9:20 A	0	0	5.40	37	2.1	430	7.8	<25		356				
		2/7/51 8:30 A	0	0	4.85	33	2.2		7.9	<25		350				
		2/8/51 9:20 A	0	0	6.50	44	3.6	<30	7.6	<25		350				
		2/9/51 8:45 A	0	0	5.65	39	1.9	91	7.7	<25		350				
		8/27/51 7:00 A	1.4	19	5.60	60		4,600	8.4	55	12	202				
		8/28/51 6:35 A	1.3	19	5.70	61	2.0	2,400	8.2	45	12	200				
		8/29/51 6:20 A	1.8	19	5.50	59	1.3		8.2	90	9	202	0.15	0.000		
		8/30/51 6:50 A	2.6	20	6.00	65	1.7	9,300	8.4	40	16	201	0.25	0.000		Trace
		8/31/51 8:00 A	1.9	17	6.20	64	1.7	9,300	8.4	30	13	190				
		9/1/51 9:15 A	1.9	18	6.20	65	1.4		8.1	30	4	186	0.25	0.000		Trace
James River Bridge Highway No.12 East of Aberdeen, South Dakota	J.R. 398	2/5/51 9:55 A	0	0	0.25	2	7.7	<30	7.0	40		645				
		2/6/51 10:05 A	0	0	0.40	3	1.9	<30	8.1	<25	Trace	690				
		2/7/51 9:20 A	0	0	0.20	1	8.2		7.8	35		645				
		2/8/51 10:05 A	0	0	0.45	3	16.2	36	7.6	<25		635				
		2/9/51 10:00 A	0	0	0.15	1	13.5	36	7.6	<25		650				
		8/27/51 9:30 A		19	4.80	51		4,600	8.4	90	25	226				
		8/28/51 8:45 A		21	5.00	56	6.4	930	8.4	120	25	240				
		8/29/51 8:00 A		19	4.60	49	3.7		8.3	90	12	227	0.05	0.000		
		8/30/51 8:30 A		21	5.30	59	4.6	9,300	8.6	120	24	218	0.10	0.000		1.0
		8/31/51 9:40 A		18	6.20	65	4.8	360	8.5	90	26	219				
		9/1/51 7:45 A		18	5.70	60	4.3		8.3	100	8	222	0.10	0.000		1.0
Moccasin Creek - West of Warner, S.D.	J.R. 378 M.C. 25	8/27/51 10:15 A		18	6.05	63	-	2,300	8.2	150	-	259				
		8/28/51 9:40 A		22	4.45	50	5.2	2,300	8.2	<25	10	222				
		8/29/51 8:25 A		19	3.20	34	3.0		8.1	40	5	225	0.30	0.000		
		8/30/51 9:15 A		21	2.85	32	5.5	2,300	8.0	<25	Trace	231	1.00	0.000		20
		8/31/51 10:20 A		17	7.70	79	3.2	15,000	8.2	<25	7	209				
		9/1/51 8:50 A		17	3.90	40	6.0	-	7.9	35	0	208	1.60	0.000		22
James River - Bridge 7-1/2 mi. East of Warner, South Dakota	J.R. 372	2/5/51 10:30 A	0	0	0.05	0	21.7	4,300	7.1	45		775				
		2/6/51 10:30 A	0	0	0.00	0	22.0	430	7.1	<25		835				
		2/7/51 9:40 A	0	0	0.25	2	16.3	-	7.8	35		810				
		2/8/51 10:30 A	0	0	0.05	0	17.2	2,400	7.7	30		830				
		2/9/51 10:25 A	0	0	0.10	1	41.3	2,400	7.7	<25		830				
		8/27/51 10:00 A	0.5	18	5.80	61	-	2,300	8.5	160	27	225				

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Mileage from Mouth	Date	Avg. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5-Day B.O.D. p.p.m.	Coliform M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkalinity p.p.m. CO3	Alkalinity p.p.m. HCO3	Nitrogen - N p.p.m. NH3	Nitrogen - N p.p.m. NO2	Nitrogen - N p.p.m. NO3	PO4
James River - Bridge	J.R. 372	8/28/51 10:05 A	0.3	22	5.95	67	9.4	2,300	8.6	160	31	235				
7-1/2 mi. East of Warner, South Dakota		8/29/51 8:25 A	0.5	19	3.60	38	7.2	-	8.6	200	23	238	0.10	0.000		
(cont'd.)		8/30/51 9:00 A	1.2	21	3.10	34	6.4	4,300	8.6	200	25	237	Trace	0.000		1.0
		8/31/51 10:05 A	1.2	18	5.40	57	7.8	2,100	8.7	160	18	245				
		9/1/51 9:15 A	1.1	18	4.75	50	7.6	-	8.5	170	12	232	0.10	0.000		Trace
James River	J.R. 303	2/5/51 11:20 A	2	0	0.60	4	12.1	930	7.0	<25		720				
Bridge 3/4 mi. northeast of Ashton, S.D.		2/6/51 11:10 A	2	0	1.00	7	8.7	930	7.4	<25		875				
		2/7/51 10:25 A	2	0	0.90	6	7.3	-	7.7	<25		815				
		2/8/51 11:10 A	2	0	0.90	6	8.7	930	7.3	<25		835				
		2/9/51 11:05 A	2	0	0.90	6	9.8	2,300	7.7	<25		860				
		8/27/51 11:00 A	3.7	21	7.40	82	-	91	8.4	140	22	232				
		8/28/51 11:00 A	2.5	23	6.75	78	5.7	430	8.4	150	21	249				
		8/29/51 9:15 A	1.4	20	4.80	52	4.3	-	8.4	170	15	256	0.10	0.000		
		8/30/51 9:50 A	1.0	23	5.95	69	3.2	>9,300	8.4	160	28	176	0.15	0.000		1.0
		8/31/51 10:55 A	0.5	19	7.00	75	2.7	1,500	8.4	160	13	253				
		9/1/51 9:50 A	0	19	7.05	75	3.7	-	8.2	120	3	246	Trace	Trace		0.0
James River	J.R. 292	8/27/51 11:15 A	5.5	21	6.95	77	-	<300	8.3	100	17	215				
Bridge 4 miles Northeast of Redfield, S. D.		8/28/51 11:15 A	5.5	24	7.40	87	6.2	730	8.4	85	26	243				
		8/29/51 9:30 A	4.3	20	4.90	53	3.3	-	8.5	90	25	223	Trace	0.000		
		8/30/51 10:10 A	4.0	24	5.95	70	4.8	430	8.5	70	22	202	0.10	0.000		1.0
		8/31/51 11:10 A	2.0	20	7.35	80	5.6	230	8.5	80	20	244				
		9/1/51 10:05 A	3.3	19	6.30	67	5.6		8.4	85	7	236	Trace	0.000		0.0
James River	J.R. 278	3/22/50		1	2.00	14										
Highway No. 212		2/5/51 Noon	0	0	0.00	0	12.5	93,000	7.1	95		680				
Bridge 2 mi. west of Frankfort, S.D.		2/6/51 11:45 A	0	0	0.00	0	12.7	43,000	7.1	40		750				
		2/7/51 10:55 A	0	0	0.00	0	11.3	-	7.8	60		730				
		2/8/51 11:45 A	0	0	0.00	0	12.7	240,000	7.4	45		750				
		2/9/51 11:35 A	0	0	0.00	0	13.0	240,000	7.7	30		750				
James River	J.R. 224	3/22/50		1	0.10	1										
4th Street Bridge Northeast City Limits of Huron, S.D.		2/5/51 2:30 P	0	0	19.55	134	9.8	< 30	7.7	<25		550				
		2/6/51 1:00 P	0	0	23.00	157	14.2	< 30	8.1	<25	7	575				
		2/7/51 1:30 P	0	0	23.20	159	11.8	-	8.3	<25	20	560				
		2/8/51 2:00 P	0	0	18.40	126	13.8	< 30	7.9	<25		580				
		2/9/51 1:30 P	0	0	19.35	132	12.4	< 30	7.9	<25		585				
James River	J.R. 223	8/27/51 12:30 P	0	23	12.60	145	-	390	8.6	130	18	173				
Huron, S.D. water plant intake		8/28/51 12:30 P	0	23	3.55	41	11.3	430	8.5	150	19	210				
		8/29/51 10:45 A	5	23	7.90	91	7.7	-	8.8	120	22	198	Trace	Trace		
		8/30/51 11:30 A	8	25	6.60	79	4.0	1,500	8.8	80	24	199	0.55	0.000		Trace
		8/31/51 12:30 P	23	22	5.15	58	4.7	2,400	8.7	100	15	204				
		9/1/51 11:10	0	21	4.05	45	5.5	-	8.5	90	8	136	0.50	Trace		1.0

LABORATORY DATA

SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Mileage from Mouth	Date	Avg. disch. c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkalinity p.p.m.		Nitrogen - N p.p.m.			PO4
					p.p.m.	% Sat.					CO3	HCO3	NH3	NO2	NO3	
James River	J.R. 222.9	8/27/51 12:40 P	0	22	7.70	87	-	4,300	8.6	100	10	199				
Highway No. 14 Bridge at Huron, S.D.		8/28/51 12:45 P	0	26	7.75	91	12.4	4,600	8.8	110	28	184				
		8/29/51 10:50 A	5	23	5.55	64	9.1	-	9.0	130	27	190	0.00	0.000		
		8/30/51 11:40 A	8	25	4.70	56	4.1	230	8.9	60	26	197	0.15	0.000		0.0
		8/31/51 12:40 P	23	27	6.30	71	4.9	2,400	8.8	140	22	221				
		9/1/51 11:30 A	0	20	2.95	32	6.5	-	8.6	120	12	183	0.70	0.005		Trace
James River	J.R. 221	3/22/50		1	0.70	8										
County Br. Southeast City limits of Huron, South Dakota		2/5/51 1:00 P	6	0	2.20	15	31.0	460,000	7.5	60		535				
		2/6/51 3:30 P	6	0	6.80	47	16.2	93,000	7.7	85		545				
		2/7/51 2:00 P	6	0	7.90	54	23.8	-	7.9	40		590				
		2/8/51 2:30 P	6	0	4.65	32	28.0	930,000	7.7	55		575				
		2/9/51 2:00 P	6	0	1.80	12	26.0	930,000	7.9	35		585				
		8/27/51 2:55 P		23	11.50	132	-	9,100	8.7	140	13	190				
		8/28/51 1:30 P		25	17.20	205	19.8	2,300	9.2	120	47	185				
		8/29/51 1:40 P		25	8.30	99	13.5	-	9.0	150	26	180	1.00	0.030		
		8/30/51 12:50 P		28	20.90	264	22.0	9,300	9.2	120	42	189	1.00	0.020		1.5
		8/31/51 12:45 P		22	8.40	95	12.5	4,300	8.9	110	22	178				
		9/1/51 1:30 P		21	8.25	92	15.8	-	8.2	130	3	180	1.40	0.170		4.0
James River	J.R. 216	8/27/51 2:30 P		25	14.05	168	-	9,300	8.7	240	12	178				
County Bridge, 5 mi. south of Huron, S.D.		8/28/51 1:05 P		26	12.35	150	7.1	9,300	9.0	190	20	169				
		8/29/51 [illegible]		26	9.40	114	9.8	-	9.0	210	23	173	0.45	0.000		
		8/30/51 12:30 P		28	12.80	162	10.0	9,300	9.0	180	27	191	Trace	0.000		0.0
		8/31/51 12:20 P		22	10.90	123	20.6	2,300	8.8	170	18	176				
		9/1/51 12:30 P		20	7.35	80	12.6	-	8.5	160	8	199	0.10	Trace		0.0
James River	J.R. 206	8/27/51 1:55 P	59	27	13.90	172		930	8.5	210	20	230				
11 miles south and 4 miles east of Huron, South Dakota		8/28/51 12:35 P	50	28	11.45	145	6.0	2,400	8.8	210	-	-				
		8/29/51 12:45 P	47	27	10.55	131	7.6	-	8.8	260	28	237	0.10	0.000		
		8/30/51 Noon	44	29	10.25	132	8.7	4,300	8.6	170	20	195	0.10	0.000		1.0
		8/31/51 11:35 A	43	22	9.80	111	8.5	750	8.6	150	17	221				
		9/1/51 11:15 A	38	20	8.10	88	7.2	-	8.3	160	5	207	Trace	0.000		1.0
James River	J.R. 182	3/22/50		1	7.30	51										
Bridge Highway No. 37, 3/4 mi. south of Forestburg, S.D.		2/5/51 11:15 A	8.5	0.5	9.90	69	3.7	< 30	7.6	<25		630				
		2/6/51 12:20 P	8.5	0.5	11.20	78	3.8	< 30	7.6	<25		640				
		2/7/51 12:35 P	8.5	0.5	12.70	84	3.5	-	8.0	<25		660				
		2/8/51 11:25 A	8.5	0.5	11.35	79	3.1	< 30	7.7	<25		670				
		2/9/51 Noon	8.5	0.5	8.20	57	2.4	< 30	7.7	<25		675				
James River	J. R. 146	2/5/51 10:45 A	10	0.5	20.20	140	5.1	< 30	7.8	<25		630				
3 miles north and 2 miles east of Mitchell, South Dakota		2/6/51 11:45 A	10	0.5	16.80	116	6.2	36	8.0	<25		-				
		2/7/51 11:05 A	10	0.5	21.10	146	2.3	-	8.2	<25	4	570				

LABORATORY DATA

SUMMARY OF INDIVIDUAL SAMPLES

Sampling Point	Mileage from Mouth	Date	Avg. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5-Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	pH	Turb. p.p.m.	Alkalinity p.p.m. CO_3	Alkalinity p.p.m. HCO_3	Nitrogen - N p.p.m. NH_3	Nitrogen - N p.p.m. NO_2	Nitrogen - N p.p.m. NO_3	PO_4
James River	J.R. 146	2/8/51 10:55 A	10	0.5	20.70	157	3.3	< 30	7.7	<25		680				
3 miles north and 2 miles east of		2/9/51 11:50 A	10	0.5	21.85	158	4.4	< 30	8.0	<25		630				
Mitchell, South Dakota (cont'd.)		8/27/51 12:55 P		26	7.40	87	-	4,600	8.4	180	21	200				
		8/28/51 11:25 A		25	7.90	89	5.8	11,000	8.6	200	28	210				
		8/29/51 11:45 A		26	5.70	69	6.7	-	8.6	160	17	209	0.10	Trace		
		8/30/51 10:55 A		27	5.40	67	6.3	2,300	8.5	150	18	222	0.00	0.000		Trace
		8/31/51 10:30 A		23	6.80	78	6.1	360	8.6	110	18	227				
		9/1/51 9:45 A		21	5.25	58	7.8	-	8.3	120	4	209	Trace	0.700		Trace
James River	J.R. 139	2/5/51 10:25 A	15	2	8.35	60	2.3	<30	7.4	<25		530				
2 miles east of Mitchell, South Dakota		2/6/51 11:00 A	15	2	10.00	72	1.8	<30	7.6	<25		525				
below low head dam		2/7/51 10:40 A	15	1	10.20	72	5.2	-	8.0	<25		550				
		2/8/51 10:30 A	15	1	10.85	76	4.5	36	7.7	<25		550				
		2/9/51 11:20 A	15	1	11.35	80	3.3	36	7.7	<25		535				
James River	J.R. 128	1/26/50		1	0.00	0										
Bridge 5 mi. east and 5 mi. south of		2/5/51 10:10 A	15	0.5	1.60	11	18.5	1,100,000	7.3	< 25		495				
Mitchell, South Dakota		2/6/51 11:00 A	15	0.5	5.50	38	5.5	9,300	7.5	< 25		410				
		2/7/51 10:20 A	15	0.5	2.95	20	7.8	-	7.9	< 25		510				
		2/8/51 10:10 A	15	0.5	2.30	16	8.5	430,000	7.5	< 25		495				
		2/9/51 11:00 A	15	0.5	1.80	12	18.0	230,000	7.5	< 25		495				
		8/27/51 11:15 A		22	5.05	57	-	2,300	8.1	180	-	216				
		8/28/51 10:10 A		24	5.60	66	12.4	4,300	8.3	130	8	212				
		8/29/51 10:20 A		24	6.50	76	2.8	-	8.3	120	13	210	0.60	Trace		
		8/30/51 9:40 A		26	6.30	77	3.8	2,300	8.4	120	14	183	0.45	Trace		Trace
		8/31/51 9:30 A		22	6.20	68	5.6	910	8.4	120	7	196				
		9/1/51 6:30 A		23	8.40	97	5.2	-	8.3	140	4	197	0.45	0.015		0.0
James River	J.R. 96	2/5/51 9:30 A	20	1	15.20	107	4.8	<300	7.6	<25		555				
Bridge at Milltown, South Dakota		2/6/51 10:20 A	20	1	16.20	114	3.1	< 30	7.6	<25		540				
		2/7/51 9:45 A	20	1	16.30	115	3.9	-	8.1	<25	Trace	550				
		2/8/51 9:30 A	20	1	15.90	112	4.6	36	7.7	<25		515				
		2/9/51 10:30 A	20	1	16.10	113	5.2	36	7.9	25		505				
		8/27/51 10:15 A		22	7.35	83	-	24,000	8.1	200	8	174				
		8/28/51 9:05 A		22	7.40	84	9.1	930	8.4	230	12	173				
		8/29/51 9:15 A		24	6.65	78	4.0	-	8.4	150	18	196	0.15	Trace		
		8/30/51 8:45 A		26	6.50	79	5.2	230	8.2	120	12	193	0.10	0.000		Trace
		8/31/51 8:30 A		22	4.45	50	4.6	930	8.3	120	11	201				
		9/1/51 5:45 A		23	7.40	85	5.2	-	8.3		4	197	0.45	0.010		0.0
James River	J.R. 55	2/5/51 9:00 A	25	0.5	19.40	135	5.8	<30	7.5	<25		450				
Highway No. 18 Bridge 1/5 mi. east		2/6/51 9:35 A	25	0.5	18.30	127	3.8	<30	7.5	<25		310				
of Olivet, S. D.		2/7/51 9:15 A	25	0.5	19.85	138	4.9	-	7.9	<25		445				
		2/8/51 9:00 A	25	0.5	20.40	141	4.0	<30	7.7	<25		400				
		2/9/51 9:10 A	25	0.5	19.60	136	3.4	<30	7.9	<25		430				

LABORATORY DATA

SUMMARY OF [illegible] RESULTS

Sampling Point	Mileage from Mouth	Date	Avg. Discharge c.f.s.	Temp. °C	Dissolved Oxygen		5-Day B.O.D. p.p.m.	Coliform M.P.N. per 100 ml.	pH	Turb. p.p.m.	Alkalinity p.p.m.		Nitrogen - N p.p.m.			PO_4
					p.p.m.	% Sat.					CO_3	HCO_3	NH_3	NO_2	NO_3	
James River Bridge, Highway No. 81, 12 miles north of Yankton, S. D.	J.R. [illegible]	[illegible] A	[illegible]	0.5	25.75	178	3.8	36	7.5	<25		430				
		[illegible] A	[illegible]	0.5	22.65	157	5.8	<30	7.5	<25		430				
		[illegible] A	[illegible]	0.5	23.05	160	3.3	-	7.9	<25		410				
		[illegible] A	[illegible]	0.5	23.60	164	4.7	<30	8.0	<25		415				
		[illegible] A	[illegible]	0.5	22.30	155	3.0	<30	7.8	<25		410				

LABORATORY DATA

[illegible]

Station	Mileage from Mouth	Date 1951	[illegible]	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.			pH	Alkalinity p.p.m. CO3	Alkalinity p.p.m. HCO3		Nitrogen - N p.p.m. [illegible]	Nitrogen - N p.p.m. [illegible]		[illegible]
1	449	9/10/51	18	15	10.6	105			9.5	111	104		0.0	0.0		0.0
2	450	4/4/51	920	2	11.6	107			7.9	0	138					Trace
		9/10/51	18	16	8.9	90			8.5	36	284		Trace	0.0		1.0
4	430	4/4/51	-10	7	9.6	69			7.6	0	98					0.0
5	413	4/5/51	920	2	8.4	61			7.6	0	68					0.0
		9/10/51	0	18	10.8	113			8.5	88	209		0.0	0.0		0.0
6	382	4/4/51		6	8.4	67			7.9	0	178					1.0
7	353	4/3/51	880	6	6.8	94			7.6	0	130					1.0
8	298	4/3/51		5	8.4	66			7.3	0	180					1.0
		9/11/51	4.6	20	9.8	104			8.5	14	208		0.0	0.0		0.0
9	271	9/11/51	0	21	8.4	98			8.5	17	224		0.0	0.0		0.0
10	259	9/11/51	0	20	8.8	100			8.5	20	220					0.0
	254	4/3/51		7	8.4	69			7.5	0	141					1.0
11	252	4/3/51	490	3	6.4	47			7.3	0	147					1.0
		9/11/51	6	21	9.6	107			8.6	38	226		0.0	0.0		0.0
12	233	9/11/51	0	20	8.0	88			8.6	26	190		0.0	0.0		0.0
13	224	4/3/51	490	8	10.2	75			7.6	0	316					1.04
		4/5/51	890	8	8.0	58			7.4	0	111					1.0
		9/6/51	0		12.0				9.1	41	156		0.0			
		9/11/51	0	20	8.0	88			8.7	38	153		0.0	0.0		0.0
14	223	4/5/51	890	2	8.0	58			7.4	0	120					1.0
		9/11/51	0	18	7.8	88			8.7	88	166		0.0	0.0		0.0
15	222	9/10/51	0	21	17.6	194			8.8	38	143		2.40	0.30		4.0
16	221	3/30/51	490	1	8.5	60			7.5	0	158					
		9/6/51	0						9.4	74	107			0.34		
		9/10/51	0	20	21.0	229			9.2	60	138		1.20	0.30		3.0
		9/11/51	0	17	18.4	189			9.3	80	88		1.25	0.24		1.0
17	220	9/10/51	0	20	19.2	209			9.4	40	188		0.0	0.28		1.0
18	219	9/10/51	0	19	15.6	167			9.3	78	198		0.0	0.33		1.0

LABORATORY DATA

SUMMARY OF INDIVIDUAL SAMPLES

Stations	Mileage from Mouth	Date 1951	Avg. disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.			pH	Alkalinity p.p.m. CO₃	Alkalinity p.p.m. HCO₃		Nitrogen - N p.p.m. NH₃	Nitrogen - N p.p.m. NO₂		PO₄
18a	212.9	9/10/51	0	20	12.0	131			9.4	80	110		0.0	0.17		0.0
19	216	3/31/51	135	1	9.4	66			7.4	0	190					Trace
		9/13/51	0	14	10.6	102			9.3	50	82		0.0	0.0		0.0
20	206	3/31/51		9	8.0	70			7.5	0	184					
		9/13/51		16	10.5	106			8.5	20	122		0.0	0.0		0.0
21	195	4/1/51	1,380	2	10.2	74			7.6	0	133					0.0
22	188	4/1/51	1,380	4	10.0	76			7.5	0	200					0.0
		9/13/51	40	18	9.6	101			8.4	20	200		0.0	0.0		0.0
23	158	9/9/51	60	21	9.2	102			8.5	40	214		0.0	0.0		0.0
25	146	4/2/51	2,100	2	9.6	69			7.5	0	99					0.0
26	142	9/9/51	60	20	16.4	173			8.4	20	206		0.80	0.0		Trace
27	139	9/7/51	50	20	8.8	96			8.5	32	184		0.0	0.0		0.0
28	138.5	4/2/51	2,100	2	10.0	72			7.6	0	102					1.0
		9/7/51	50	20	2.4	26			8.0	0	232		5.60	0.0		2.0
		9/8/51	50	19	4.2	45			8.1				1.60	0.03		Trace
29	138	9/7/51	50	19	5.4	58			8.2	8	192		0.75	0.0		0.0
		9/8/51	50	19	4.6	49			8.1				2.80	0.0		0.5
30	137	9/7/51	50	19	7.2	77			8.3	30	194		1.00	0.0		0.0
		9/8/51	50	19	4.0	43			8.2				0.80	0.01		1.0
31	136	9/7/51	50	20	4.8	52			8.2	6	213		-	Trace		1.0
		9/8/51	50	20	4.0	44			8.2				2.40	0.0		Trace
32	135	9/8/51	50	20	6.4	70			8.3				1.80	0.01		0.0
33	134	9/8/51	50	20	7.2	78			8.2				0.80	0.02		0.0
34	133	9/8/51	50	21	9.8	109			8.3	9	202		0.80	0.02		0.0
35	132	9/8/51	50	22	17.4	197			8.6	30	190		0.60	0.08		0.0
36	131.5	4/2/51	2,100	2	9.6	69			7.7	0	105					0.0
		9/8/51	50	22	16.0	181			8.6	36	190		0.70	0.08		0.0